Direct cohesive law measurement under mixed-mode loading

A. Ajdani (IUST, Iran), A. Akhavan-Safar, M.R. Ayatollahi, L.F.M. da Silva

Advanced Joining Processes Unit

Introduction

Recently, semi-circular bend (SCB) specimen was introduced for mode I, mode II, and mixed-mode I/II fracture energy measurement in adhesively bonded joints by the current authors [1]. This specimen was employed for both ductile and brittle adhesives [2]. In this work, a novel data reduction method for obtaining the cohesive law of the adhesive using digital image correlation (DIC) is proposed. The proposed method is applied to SCB specimens.

Methodology

A direct data reduction approach based on the DIC technique is introduced. First, the strain of the substrate at the interface of the adhesive is measured. Then, traction versus time is calculated using the Hook's law (Fig.1). On the other hand, separation can be measured directly using the DIC results (Fig.2). Therefore, traction versus separation diagram can be obtained. This cohesive law is then used in a finite element (FE) analysis and experimental and numerical load-displacement curves are compared to validate the proposed method (Fig.3).

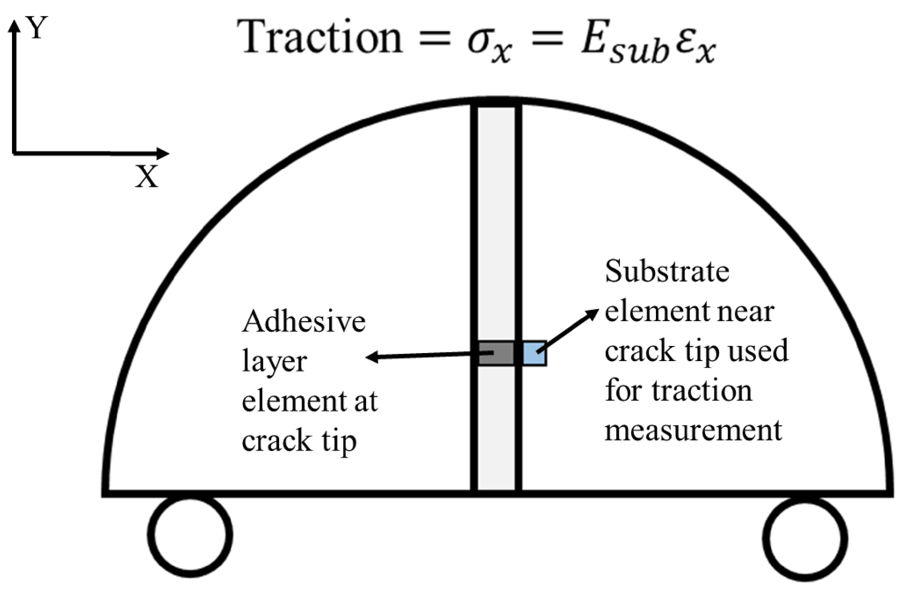

Figure 1 – Traction measuremen method.

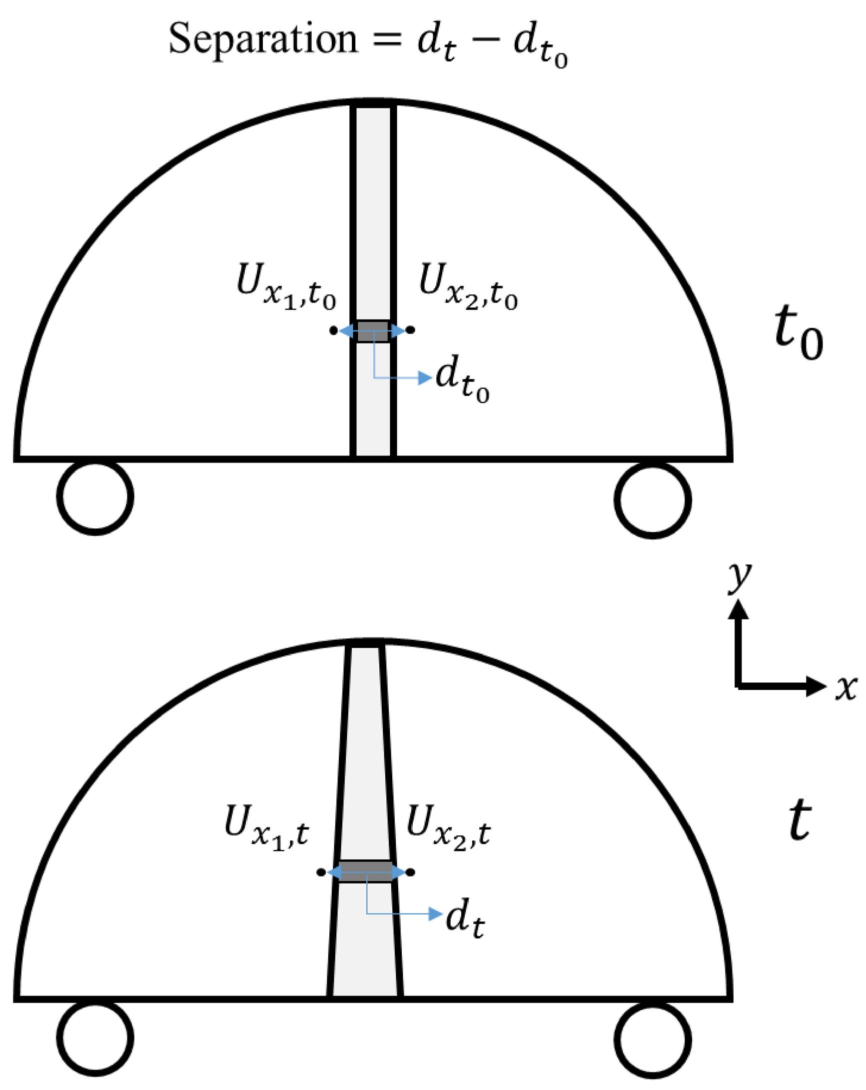

Figure 2 – Separation measurement method

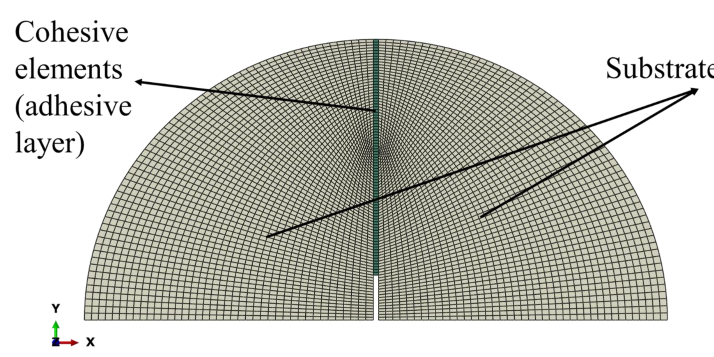

Figure 3 – Mesh used in FE analysis

Discussion

Fig. 4 shows typical strain values obtained at the adhesive/substrate interface but on the substrate. This parameter is used to measure traction applied to the adhesive layer.

Non-linear finite element analysis based on cohesive zone modelling was conducted to evaluate the proposed method. The cohesive laws obtained by this approach was used for the damage analysis of the adhesive layer in a 2-D FE simulation (Fig.5). For each specimen, more than one cohesive law can be obtained due to the crack growth. Two typical curves obtained from the two different sections of the adhesive joints are shown in Fig. 6. Fig. 7 compare the experimental and numerical results.

Experimental results

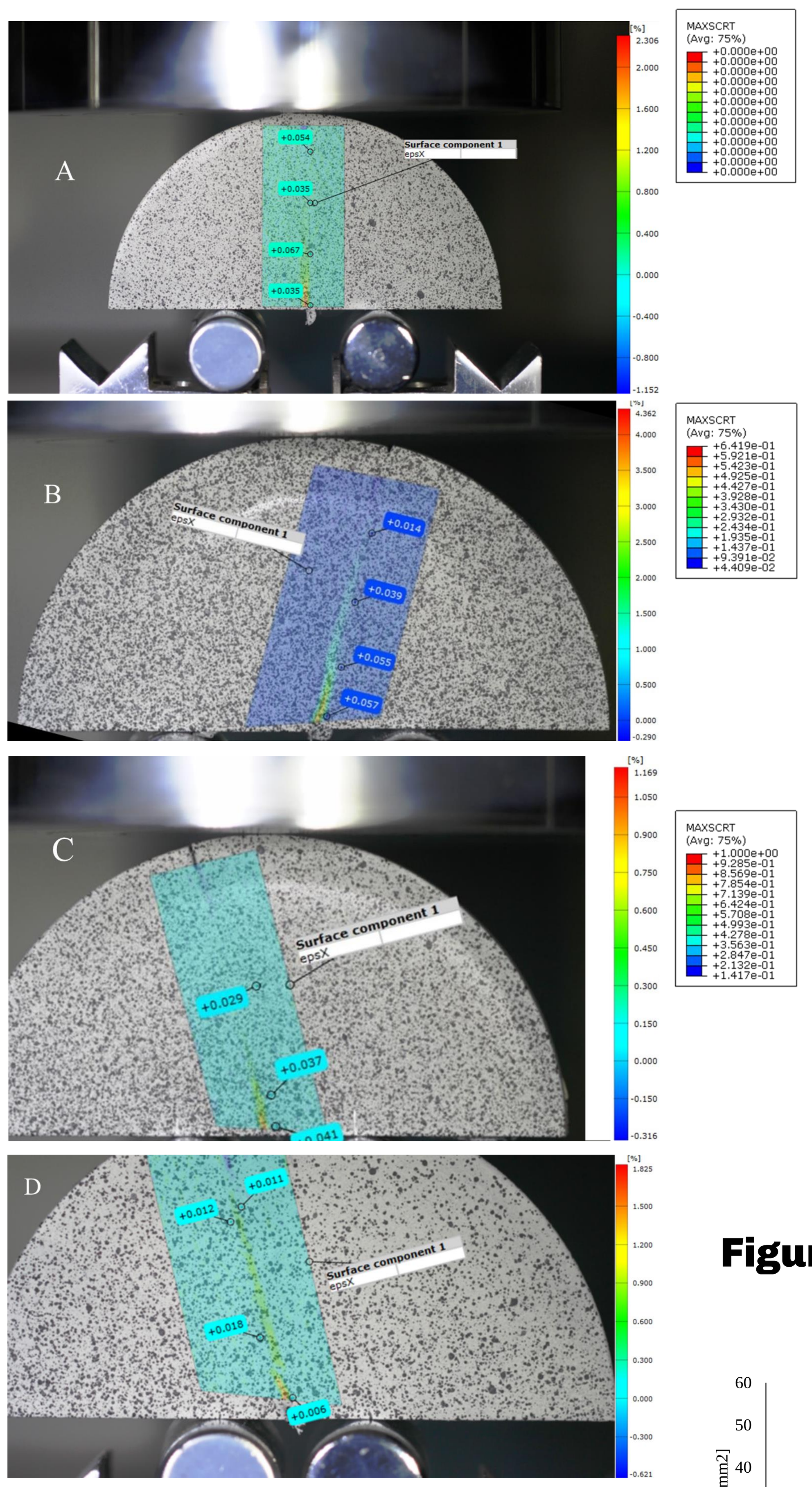

Figure 4 – ε_x Measured on substrate A)pure mode I, B) at 36 mode mixity, C) at 60 mode mixity, and D) pure mode II.

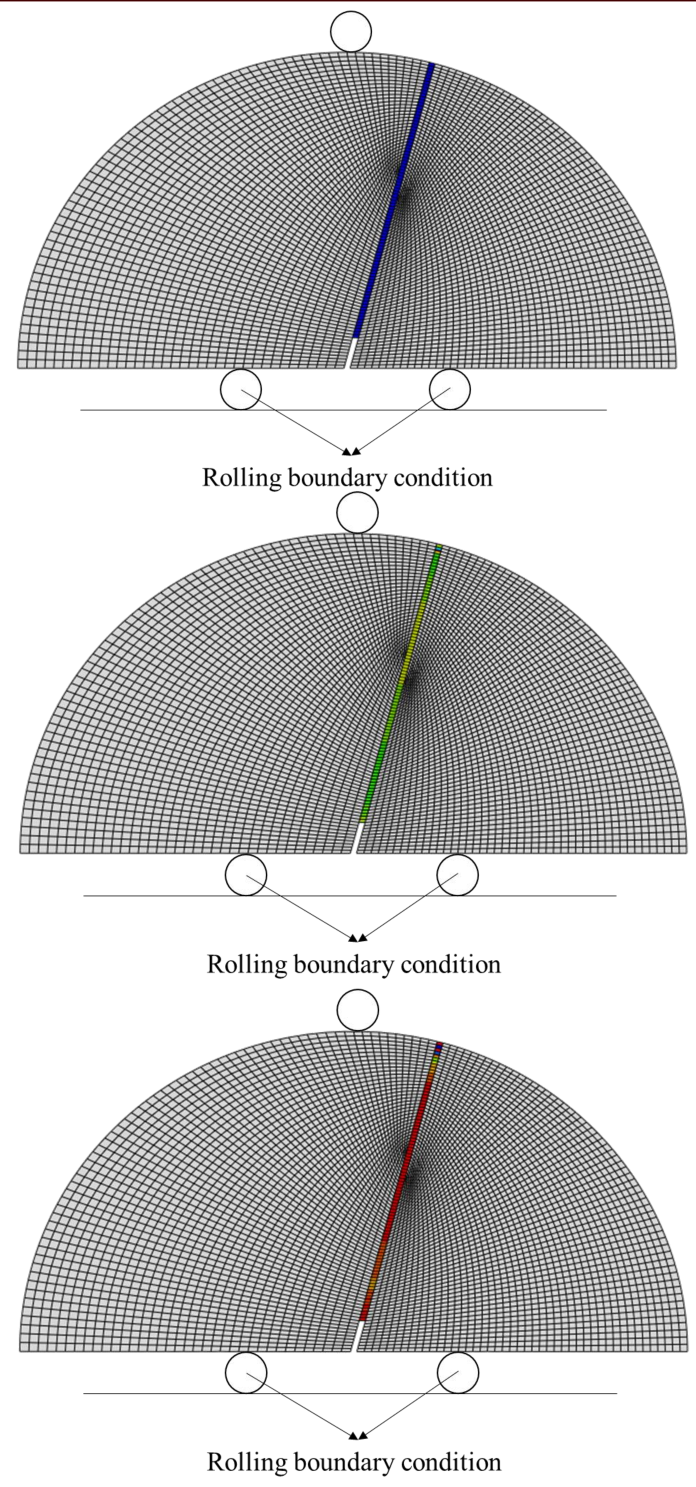

Figure 5 – Damage evolution in pure mode II simulation.

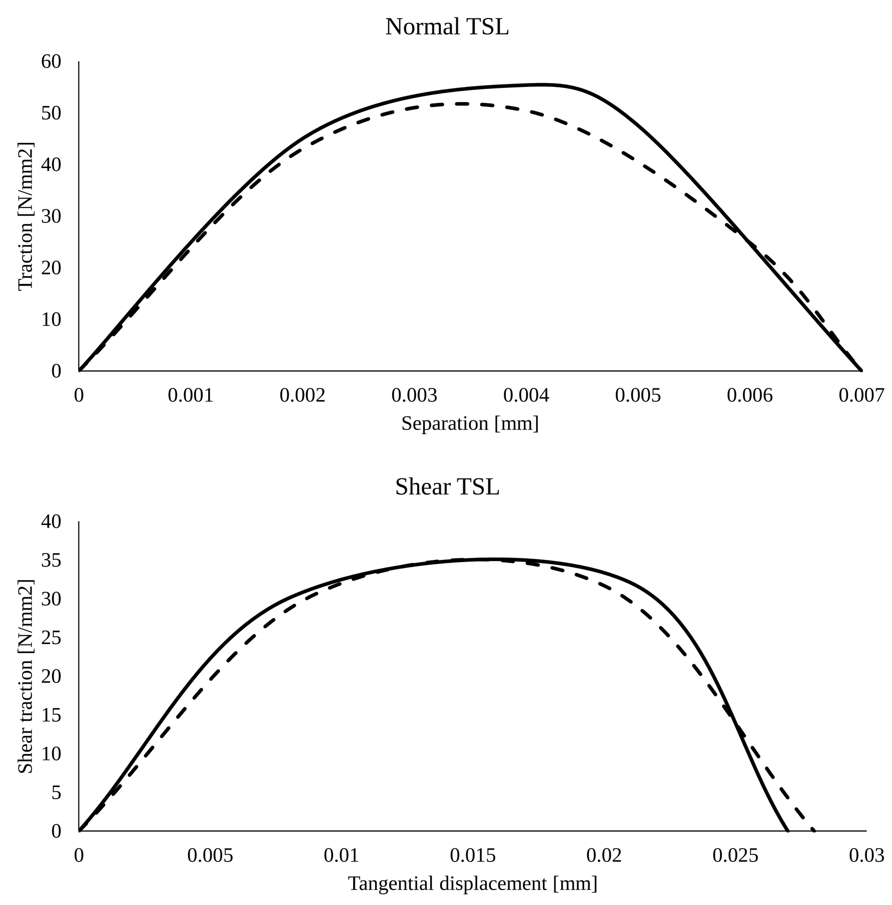

Figure 6 – Obtained cohesive laws for Pure mode I and mode II.

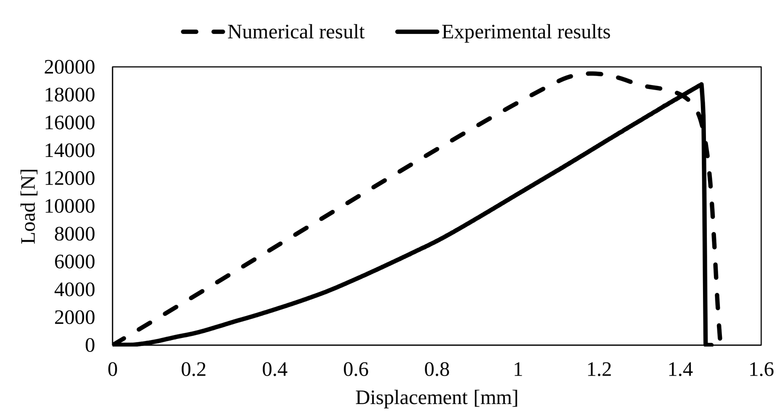

Figure 7 – A typical comparison between numerical and experimental results.

Conclusions

The proposed direct CZM method is based on the DIC technique to obtain normal and shear displacements and normal and shear tractions separately. Therefore, the cohesive law was obtained for any desired mixed-mode phase angle ratio by applying the proposed method on SCB specimens. The obtained cohesive laws were then used in a non-linear finite element simulation. An acceptable agreement was found between experiments and numerical results.

References

[1] Ajdani, A, Ayatollahi, MR, Akhavan-safar, A, da Silva, LFM, International Journal of Adhesion and Adhesives, 101 (2020): 102629.

[2] Ajdani, A, Ayatollahi, MR, da Silva, LFM, Theoretical and Applied Fracture Mechanics, 112 (2021):102927.