Analysis of Bonded Tubular Single Lap Joint subjected to varying Pressure at constant Torsion

Vikas Ranjan,

Assistant Professor

Department of Mechanical Engineering, BITS-Vizag
vikas.ranjan7@gmail.com

R.R.Das
Associate professor
Department of mechanical Engineering, ISM- Dhanbad

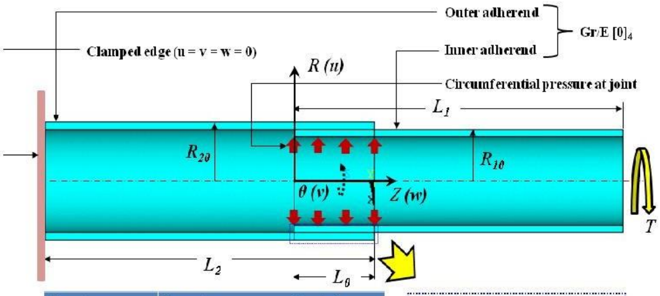
Abstract: Fiber-reinforced polymer (FRP) composites are becoming increasingly popular in the engineering applications as alternative to conventional engineering materials. The unique characteristics of FRP, such as their light weight, their resistance to corrosion, high energy absorption, and the lower cost of transportation, erection and maintenance, are very promising in the application of FRP in various engineering fields. Bonded tubular structures made with FRP composites have been common structures in various fields of engineering. The purpose of this paper is to study the combined effect of internal pressure and torsion on stress distributions and failure within the joint region. Special attention has been devoted to study the effect of pressure increase at constant torsion on the failure prone regions.

Keywords: FRP, TSLJ , Composites, Pressure, Torsion, CCW

Introduction

Two Gr/E $[0]_4$ laminated FRP composite tubes which are similar with respect to length, thickness, and properties have been used as adherends. Here zero degree fiber orientation indicates circumferentially wound fibers. The two tubes have been joined through a thin layer of adhesive (epoxy) as shown in the Figure. The bonded TSLJ have been subjected to an internal pressure of 10 MPa at the inner adherend as well as torsion loading of 100 N-m (direction of the applied torque is CCW as we see from the free end of the bonded TSLJ) at the free end of the bonded TSLJ structure. Internal pressure loading has been varied as 1MPa, 10MPa, 13 MPa, and 16 MPa for a constant torsional loading of 100 N-m in order to study the effect of circumferential pressure variation on joint strength. The material properties along with strength values for adhesive and adherends have been given. The material properties have been considered from then work of Das and Pradhan (2010). Three different bondline interfaces have been identified to be the critical regions prone to stress concentration effects in the present analysis: (i) inner adherend-adhesive interface, (ii) adhesive mid-layer, and (iii) outer adherend-adhesive interface (Figure). Two-dimensional stress distribution comparison in different cases has been over viewed in this chapter.

Specimen geometry and boundary conditions Figure shows specimen geometry and boundary conditions of the bonded single lap joint along with different interfaces at the joint region**.**



Geometry	Parameter	Magnitude
Adherend lengths	L_1 (Inner adherend) = L_2 (Outer adherend)	102.5mm
Overlap length	L_0	25 mm
Adherend thickness	t_1 (Inner adherend)= t_2 (Outer adherend)	2mm
Adhesive thickness	t_a	0.15mm
Outer radius of adherends	R_{10} (Inner adherend) R_{20} (Outer adherend)	14.40 mm 15.55 mm

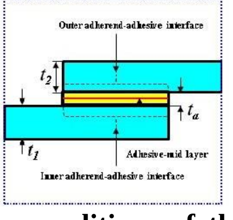
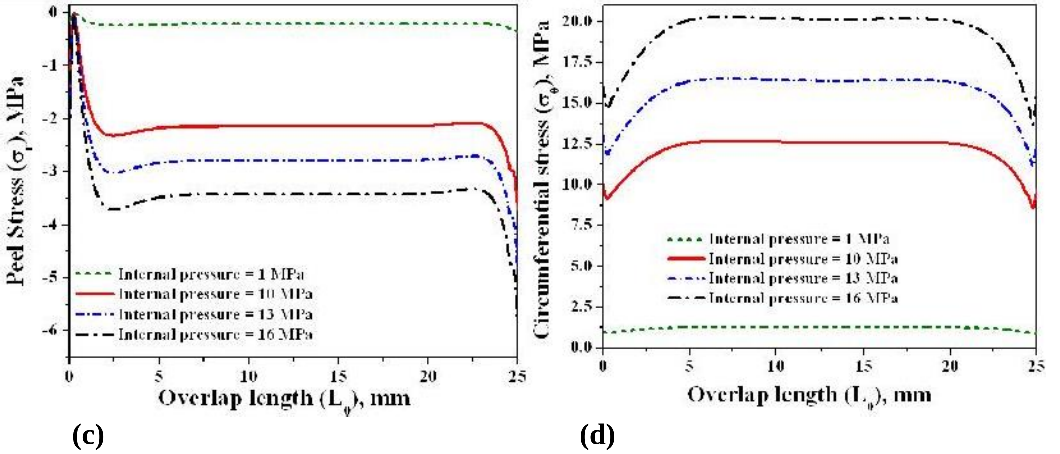


Figure 1.1. Specimen geometry and boundary conditions of the bonded single lap joint along with different interfaces at the joint region.

Results and discussion

Effect of pressure variation in presence of Torsion on stresses in the critical bondline interface

(a) **(b)**



(c) **(d)**

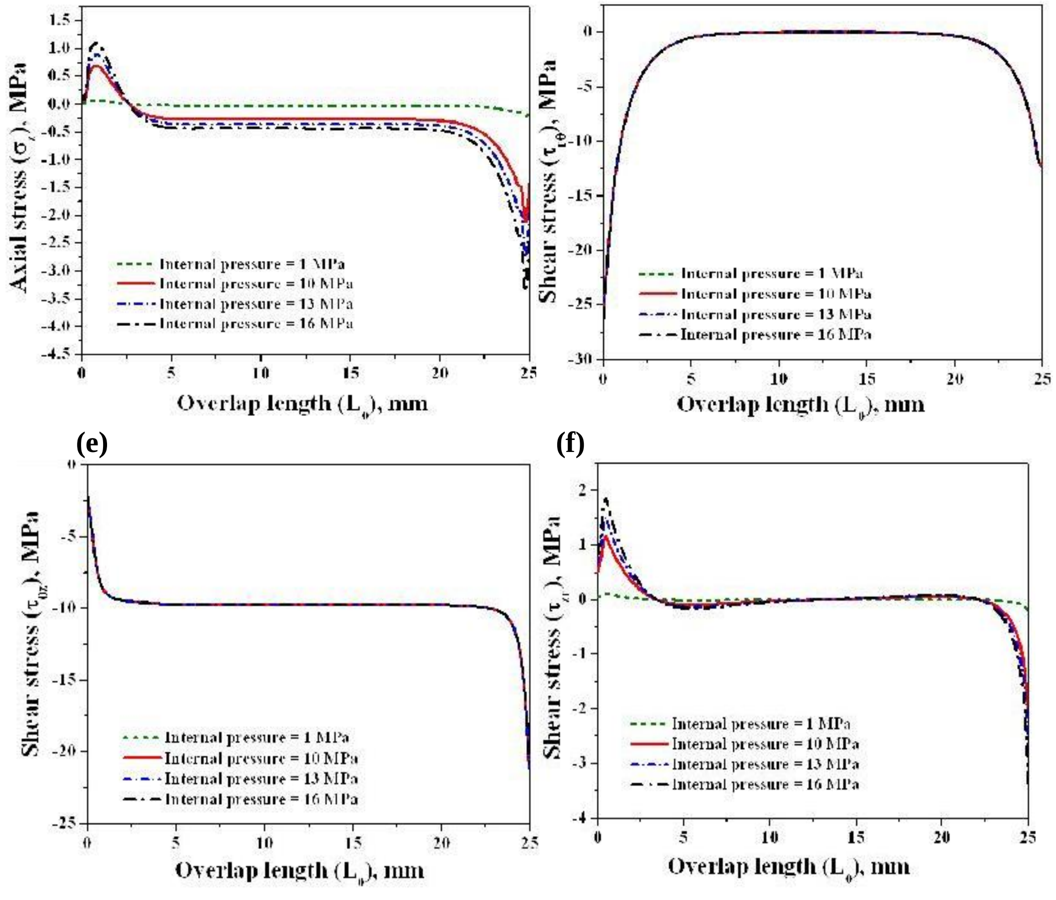


Figure1.2 Eeffect of increase in circumferential pressure in presence of torque on stress distribution within the outer adherend-adhesive interface.

As the pressure has been varied from 1MPa to 16 MPa in presence of a constant torque of 100 N-m, it can be observed that only the normal stress components (σ_r, σ_θ, and σ_z) and the radial-axial shear stress (τ_{rz}) component have been increasing. However, the remaining shear stress components ($\tau_{r\theta}$, $\tau_{\theta z}$) have remained unchanged due to the pressure variation.

Effect of pressure variation in presence of Torsion on failure at the critical bondline interface

Although variation of internal pressure at constant torsion has got impact on the stress distribution at the outer adherend-adhesive interface (Figure 6.6), but it has got negligible effect on the failure index values as shown in Figure 6.7. So increase in internal pressure has got negligible effect on the failure at the critical bondline interface.

It has been observe from the given plot that variation in magnitude of internal pressure not showing a desirable effect on the failure. It can clearly seen from failure index plot that on a small increment in pressure value, the failure indices are almost coinciding with other and also the pressure with lower magnitude found to be safe towards failure indices.

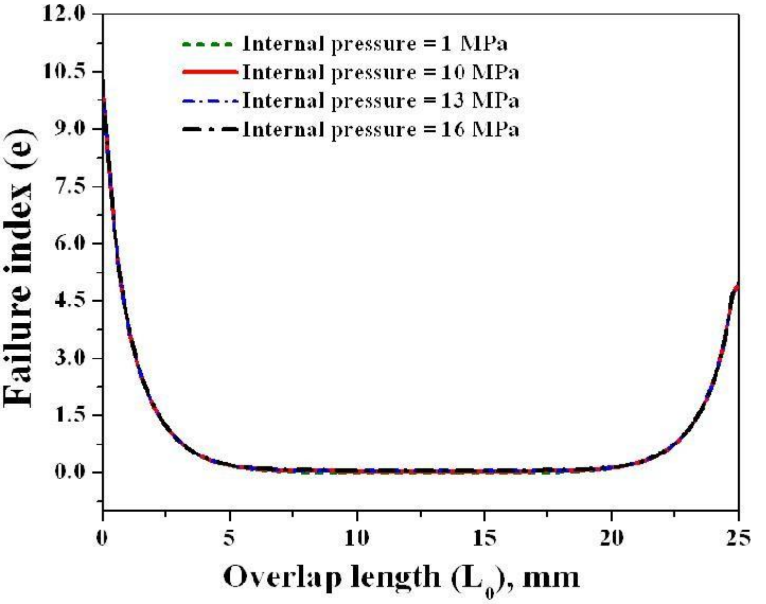


Figure. 1.3 Effect of increase in circumferential pressure in presence of torque on failure within the outer adherend-adhesive interface.

Effect of different ply-orientations on failure at the critical bondline interface due to variation of pressure at constant torsion

It is interesting to note that, as internal pressure is introduced in presence of torsional loading Gr/E $[+45/-45]_2$ ply-orientations seems to be better as it reduced the magnitude of failure indices corresponding to the critical bondline interface (Figure 6.8). The circumferentially wound fiber orientation (Gr/E $[0]_4$) and axially cross-ply orientation (Gr/E $[0/90]_2$) which have been found to be better corresponding to pure pressure and pure torsional loading have been observed to be giving comparatively greater failure index values. Hence for a combined torsional and pressure loading the angle ply-orientation (Gr/E $[+45/- 45]_2$) is most preferable.

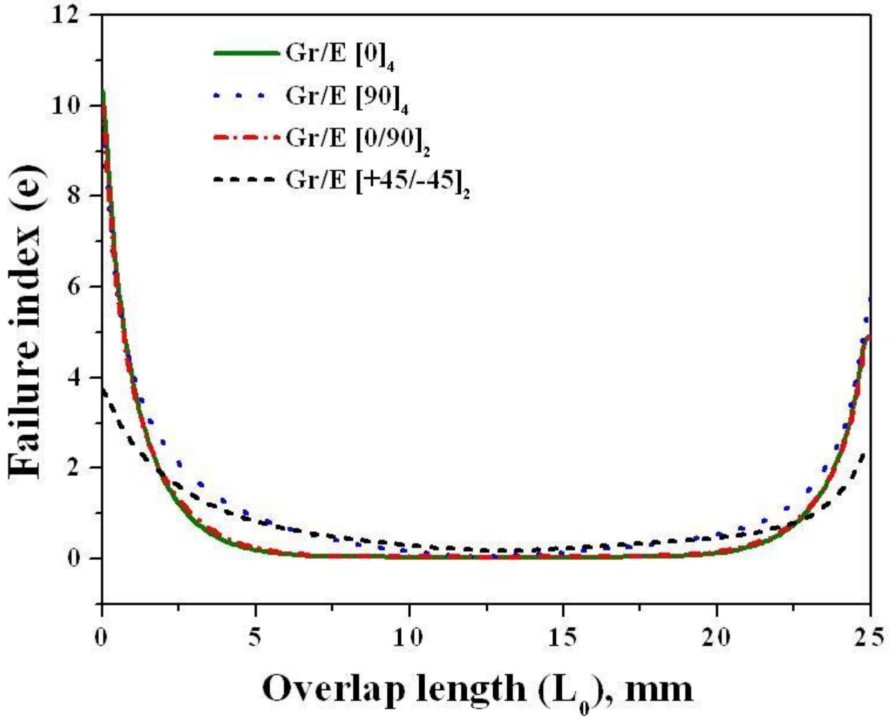


Figure 1.4 Effect of stacking sequences on Tsai-wu coupled stress criteria based failure indices at critical bondline interface under combined pressure and torsional loading

Summary and conclusions

Laminated FRP composite made bonded TSLJ subjected to a constant torsion (100 N-m) and varying internal pressure loading (1 MPa to 16 MPa) has been analyzed through finite element method. The FE codes have been developed through ANSYS APDL in a high speed IBM platform. Stress and failure effects within the joint region have been studied carefully in presence and absence of internal pressure (along with torsional loading). Finally effect of different ply orientations on the failure indices corresponding to the critical bondline interface has been studied and a suitable stacking sequence has been suggested for an improved performance of the joint. The salient conclusions have been enlisted below.

- Four stress (σ_r, σ_θ, σ_z, and τ_{rz}) components within all the bondline interfaces have been enhanced considerably (maintain the same magnitude as in the case of pure pressure loading) due to introduction of internal pressure loading along with a constant torsional loading.
- However, the remaining stress components ($\tau_{r\theta}$, $\tau_{\theta z}$) remain unaltered (maintain the same magnitude as in the case of pure torsional loading) due to introduction internal pressure loading along with a constant torsional loading.
- Introduction of internal pressure along with the pure torsional loading is marginally affecting the failure index profiles for the different bondline interfaces.
- Outer adherend-adhesive interface is the critical bondline interface which is prone to fail through adhesion failure towards the clamped edge under combined pressure and torsional loading (as in the case of pure torsional

loading).

- As the pressure has been varied, four stress components (σ_r, σ_θ, σ_z, and τ_{rz}) within the joint have been increasing. However, the remaining shear stress components ($\tau_{r\theta}$, $\tau_{\theta z}$) have remained unchanged.
- For a combined torsional and pressure loading the angle ply-orientation (Gr/E $[+45/-45]_2$) is most preferable.

References

1. **A**dams, R. D., 2005, Adhesive Bonding: Science Technology and Applications, CRC Press, England.
2. **A**dams, R.D. and Peppiatt, N.A., 1977, "Stress analysis of adhesive bonded lap joints," Journal of Adhesion, **9**, pp. 1-18.
3. **A**dams, R. D. and Wake, W. C., 1984, Structural Adhesive Joints in Engineering, Elsevier Science Publishing Company, United Kingdom.
4. **C**hen, D., and Cheng, S., 1992, "Torsional stress in tubular lap joints," International Journal of Solids and Structures, **29**, pp. 845-853.
5. **C**heng, J.C. and Li, G., 2008, "Stress analyses of smart pipe joint integrated with piezoelectric composite layers under torsion loading," International Journal of Solids and Structures, **45**, pp. 1153-1178.
6. **C**hon, T.C., 1982," Analysis of tubular lap joint in torsion," Journal of Composite Materials. **16**, pp. 268-284.