

# Study of Carbon Fiber Layout Orientation Effect on Joining with Aluminium

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## Abstract

This study seeks to investigate how different orientations of carbon fibre specifically set at 45°, 70°, and 135° impact the strength and durability of aluminium joints when bound together using epoxy resin. Understanding the relationship between the positioning of carbon fibre and the effectiveness of joining aluminium parts is crucial for optimizing structural integrity. As carbon fibre becomes increasingly integrated into aluminium structures across various industries, determining the most effective orientation for epoxy resin bonding is pivotal in enhancing the reliability of these joints and minimizing material wastage. The methodology involves adhering to the ASTM D5868 a lap shear tensile test standard, systematically arranging aluminium samples with varying carbon fibre orientations, and bonding them using epoxy resin. Three types of orientation set at 45°, 70°, and 135° named as type A, type B and type C respectively. By studying stress and strain properties, it shows that in term of stress, type C has the highest value followed by type A and B. For Strain, type B has the highest value followed by type C and A.

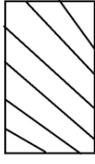
## 1. Introduction

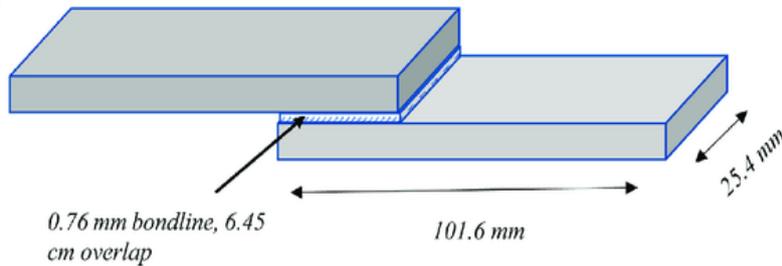
In recent years, carbon fibre technology has gained popularity because it's more cost-effective to manufacture (Zhang et al., 2023). Carbon fibre is renowned for being strong and incredibly lightweight, and it finds applications in a variety of everyday items, including machinery, aircraft, and watercraft. In the aerospace industry, carbon fibre is a key player in the manufacturing of aircraft components. It is expected in the aerospace industry, carbon fibre composite demand is expected will rose from 12 billion USD to 17 billion USD in the year 2030. The reason for this exponential demand is that this choice will make planes more fuel-efficient but also enhances their overall performance. Thanks to its remarkable strength-to-weight ratio, carbon fibre allows the creation of lightweight, robust airplane parts (Bhatt & Goe, 2017).

### 1.1 Material and methods

The purpose of the investigation is to fully comprehend how carbon fiber layout affects adhesive joining with aluminium. This is important due to lots of products such as car body and airplane fuselage using a lot of joining carbon fibre with aluminium. The result of this study will enhance the adhesive strength thus avoiding failure. The approach that will be used is by using quasi static test with ASTM D5868 standard (ASTM, 2014). The tensile strength results address the connection between the configuration of the carbon fiber layout and the adhesive strength of aluminium.

**Table 1** Carbon Fiber Layout Orientations

Type	Layer 1	Layer 2	Layer 3
<b>A</b>			
<b>B</b>			
<b>C</b>			



**Fig. 1** Specimen dimension

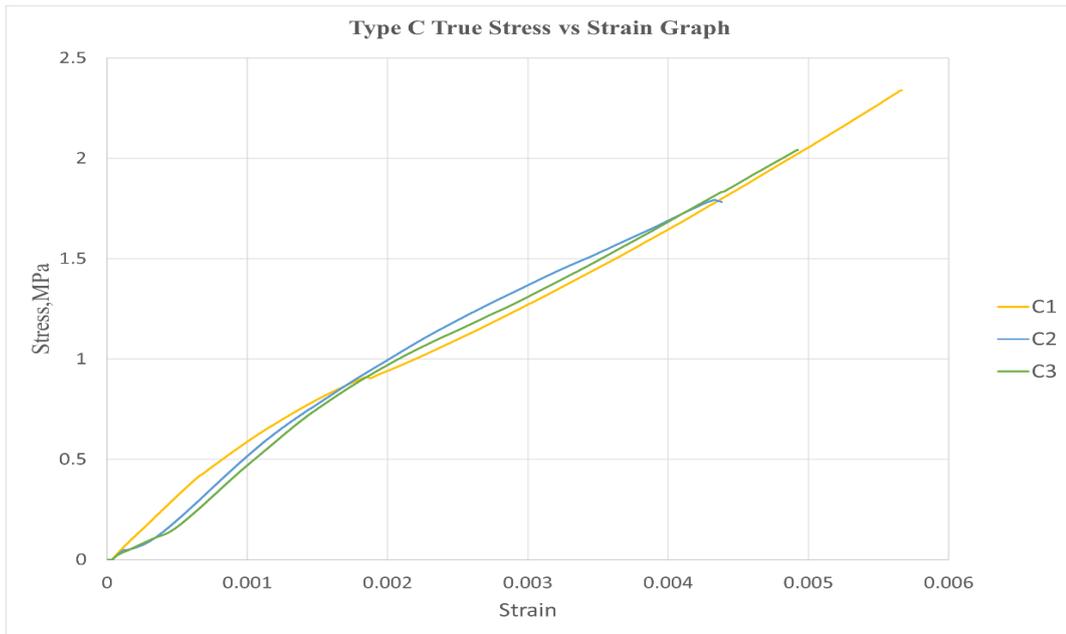
This experiment has 18 specimens consisting of nine carbon fibre plates with different layout orientation and nine plates of aluminium by following figure 1. Referring to table 1, the carbon fibre plate fabricated using 3 layers of carbon fibre fabric. The first and third layer are identical with 45° orientation. The difference between each specimen type is in the middle layer where type A uses 45° orientation, type B uses 75° orientation and type C uses 135° orientation. Preparation of carbon fiber is using hand layout method (Chaudhuri & Balaraman, 2007).

The tensile test follows the ASTM 5868 testing standard. The speed of the quasi-static machine is 13mm/min. Figure 2 shows the tensile testing machine.



**Fig. 2** Tensile testing machine

## 2. Results



**Fig. 3** True stress vs True Strain graph.

**Table 2** Type A Average Result Table

No	Max tensile (N)	Max Displacement(mm)	Max Stress (N/mm <sup>2</sup> )	Max Strain (%)
1	474.925	0.2475	4.67446	0.97441
2	1246.75	0.937	12.2712	3.68898
3	1202.25	0.8515	11.8332	3.35236
AVG	974.6	0.6787	9.593	2.672

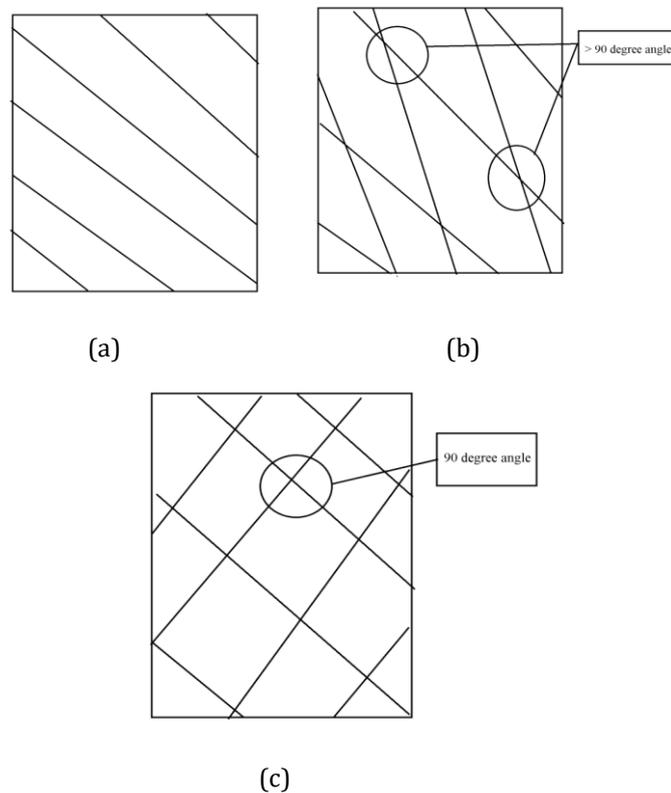
**Table 3** Type B Average Result table

No	Max tensile (N)	Max Displacement(mm)	Max Stress (N/mm <sup>2</sup> )	Max Strain (%)
1	121.3	2.20133	1.1939	8.66667
2	89.575	1.124	0.88164	4.4252
3	249.675	0.8045	2.45743	3.16732
AVG	153.5	1.377	1.511	5.420

**Table 4** Type C Average Result table

No	Max tensile (N)	Max Displacement(mm)	Max Stress (N/mm <sup>2</sup> )	Max Strain (%)
1	1500.25	1.00933	14.7662	3.97375
2	1152.25	0.77167	11.341	3.03806
3	1310.75	0.87717	12.9011	3.45341
AVG	1321.08	0.8861	13.00	3.488

### 3. Discussion



**Fig. 4** Internal layout sketch type A (a) type B (b) type C (c)

The Type A configuration aligns fibers in the same direction, creating strong structures with increased surface area overlap, enhancing strength. However, due to the lack of fiber crossing, Type A is less resistant to stretching forces, resulting in lower rigidity against tensile stress compared to type C (Chandrasekar, 2020). This layout causes type A to exhibit the lowest strain value among examined orientations, prioritizing rigidity but limiting elongation capacity due to perpendicular fiber placement.

Type B's fiber arrangement at 75° angles leads to diminished strength attributed to reduced fiber interlocking and angles smaller than 90°. This configuration compromises its ability to resist applied force, rendering type B the least robust orientation in stress management. Moreover, the 75° layout promotes increased flexibility, contributing to type B showcasing the highest strain values among all tested orientations.

Type C exhibits the highest stress levels because of its 135° fiber arrangement, bolstering structural strength by impeding the movement of applied forces. Additionally, it secures the second position in strain values owing to its perpendicular fiber layout, providing elevated flexibility under stretching forces in comparison to certain other orientations.

#### 4. CONCLUSION

In conclusion, comparing true stress vs true strain graphs for type A, B, and C specimens reveals that type C fails just before entering the elastic zone, exhibiting the highest true stress, followed by type A and B. The varied behaviors are attributed to the fiber arrangements. Type C's unique box-like pattern, formed by alternating 45° and 135° carbon fiber fabrics, provides superior strength, maintaining shape and strength until its limit. Conversely, type A's uniform layout lacks this structural advantage, limiting its endurance and causing earlier failure. Type B, with a flexible box-like shape, stretches the most, making it suitable for applications requiring flexibility despite its earlier breakage. These distinct traits showcase each orientation's utility across diverse industries.

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#### References

##### Journal

- ASTM. (2014). *Standard Test Method for Lap Shear Adhesion for Fiber Reinforced Plastic (FRP) Bonding*. Retrieved from ASTM: [astm.org/d5868-01r14.html](http://astm.org/d5868-01r14.html).
- Bhatt, P., & Goe, A. (2017). Carbon fibres: production, properties and potential use. *Mater. Sci. Res. India*, 14(1), 52-57.
- Chandrasekar, M. S. (2020). Influence of Fibre Inter-ply Orientation on the Mechanical and Free Vibration Properties of Banana Fibre Reinforced Polyester Composite Laminates. *Journal of Polymers and the Environment*, 2789 – 2800.
- Chaudhuri, R. A., & Balaraman, K. (2007). A novel method for fabrication of fiber reinforced plastic laminated plates. *Composite structures*, 77(2), 160-170.
- Zhang, J., Lin, G., Vaidya, U., & Wang, H. (2023). Past, present and future prospective of global carbon fibre composite developments and applications. *Composites Part B: Engineering*, 250, 110463.