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Deformation Analysis Of Adhesively Bonded Single Lap Joints At Variable Load

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Abstract
The increasing demand for lightweight structures and the growing utilization of lightweight materials across various industrial sectors have resulted in the widespread adoption of adhesive bonding. Recent research has focused on conducting finite element analysis to investigate the static loading analysis of adhesively bonded joints. Adhesive bonding is a method of joining materials where an adhesive solidifies between the surfaces of the adherents, resulting in an adhesive bond. Adhesively bonded joints are increasingly used as alternatives to mechanical joints in various engineering applications and offer numerous advantages over traditional mechanical fasteners.

Keywords: Single Lap, Double Lap, and Stepped Hybrid Composite

Introduction

Composite materials are extensively utilized by numerous industries, particularly the aircraft sector, owing to their lightweight nature, exceptional heat resistance, impressive strength-to-weight ratio, low density, and remarkable stiffness. Typically, mechanical fasteners are employed for joining composite materials; however, several disadvantages arise from this approach, including elevated stress concentration around the hole and restricted load transfer. Consequently, the joint's fatigue strength and fracture strength are diminished as a result. To address these issues, adhesive bonding as a joining method is recommended for connecting composite material parts. This approach ensures continuous load transfer and facilitates improved stress distribution throughout the joint. Combining mechanical joints with adhesively bonded joints proves highly advantageous for the aerospace industry in terms of performance. In this approach, the adhesive primarily bears most of the load transfer.

Hybrid joining involves the execution of two or more joining operations, either simultaneously or sequentially. The most commonly encountered form of the hybrid joint comprises an adhesive alongside a point connection, such as a mechanical fastener or a spot weld. Hybrid joining is predominantly employed in joining plate materials, although it also finds applications in expulsion and thin castings. The primary benefits of combining a point joining method with an adhesive include improved strength (both static and dynamic), the creation of continuous and leak-tight joints, enhanced resistance to impact and peel, and heightened joint stiffness. The significance of joint geometry and adhesive, mechanical properties in influencing load transfer distribution within the joint has been established. Building upon previous research, the paper investigates these joints' static strength, failure mechanisms, and fatigue resistance. The adhesive bonding technique involves integrating materials by placing an adhesive between the contacting surfaces of the parts, known as adherents, and applying heat, pressure, or both to create the joint. Adhesive joints possess desirable characteristics such as thermal and electrical insulation, a smooth surface appearance, and the ability to achieve uniform stress distribution. Adhesive joining shares similarities with the soldering and brazing processes used for metals. In adhesive bonding, a metallurgical connection is not formed as the joined surfaces are not melted; instead, they are bonded together using substances such as glue, cement, mucilage (sticky liquids from plants), or paste. Adhesive bonding offers advantages such as bonding dissimilar materials at low processing temperatures ranging from 65 to 175°C. It is particularly effective for joining thin gauge materials. While natural adhesives derived from organic and inorganic sources exist, synthetic organic polymers are commonly used for the adhesive bonding of metals. Various types of adhesively bonded joints are shown in the figure below.

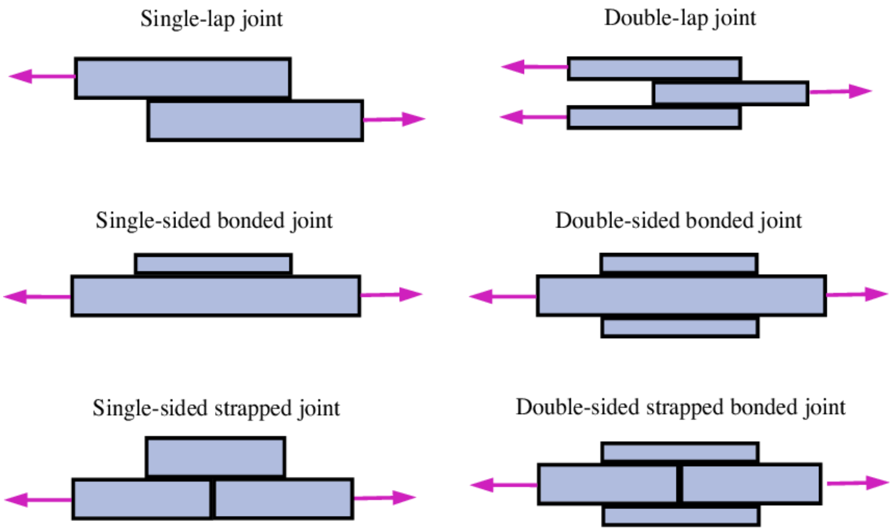

Fig. 01 Various types of adhesively bonded joints. (Ref 3. Xiang-fa Wu, Youhao Zhao)

Methodology

The present study investigates the single-lap, double-lap, and stepped hybrid composite joints. To meet the study's objectives, the design of these joints has been developed using SOLIDWORKS 2014 with 18.1. The deformations in each direction are analyzed for four different loads (1500 N, 2000 N, 2500 N, 3000 N) applied at the end of each joint. The results are then compared with the single-lap hybrid composite joint for further analysis.

Fig. 02 Single, Double & Stepped lap joints

The current study focuses on modeling geometry and conducting computational analysis of the single-lap hybrid composite joint, double-lap hybrid, and stepped hybrid composite joint. The ANSYS analysis reveals that when different tensile loads of 1500 N, 2000 N, 2500 N, and 3000 N are applied at the ends of the single-lap hybrid composite joint, double-lap hybrid composite joint, and stepped hybrid composite joint, the maximum deformations obtained are 0.476mm, 0.028mm, and 0.033mm, respectively. The maximum deformation observed in the X-direction of the model can be attributed to the fact that the applied load is also in the same direction.

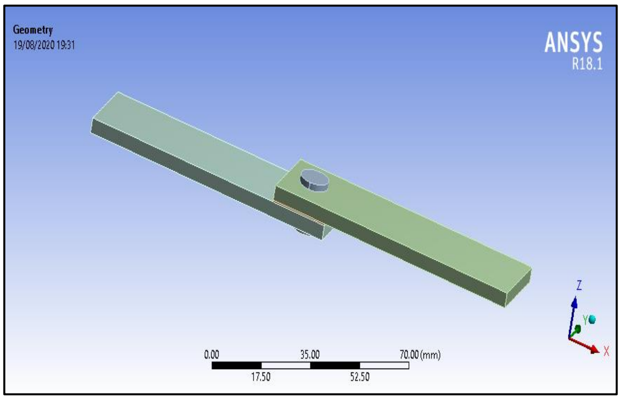

Fig.3 Imported CAD model of Single lap hybrid joint in ANSY

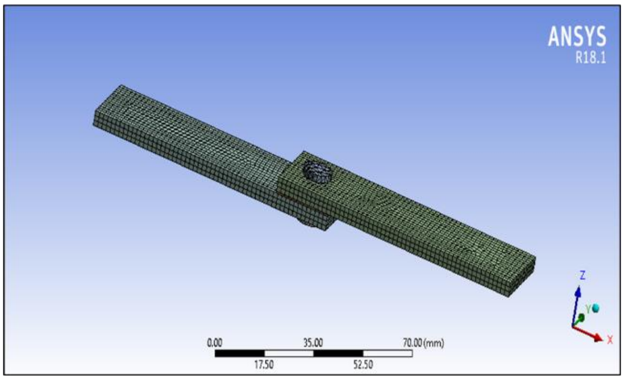

Fig 4 Meshed CAD model of single lap hybrid joint in ANSYS.

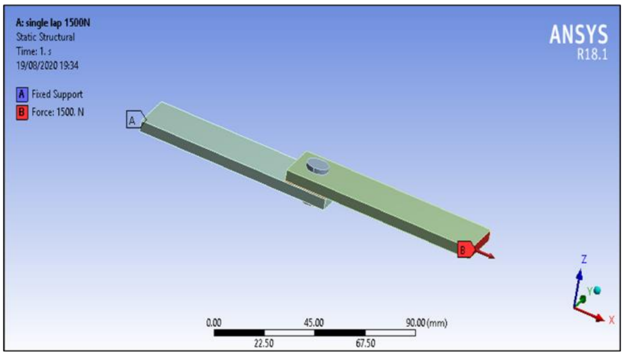

Fig.5 Loads and Boundary Conditions in single lap hybrid joint.

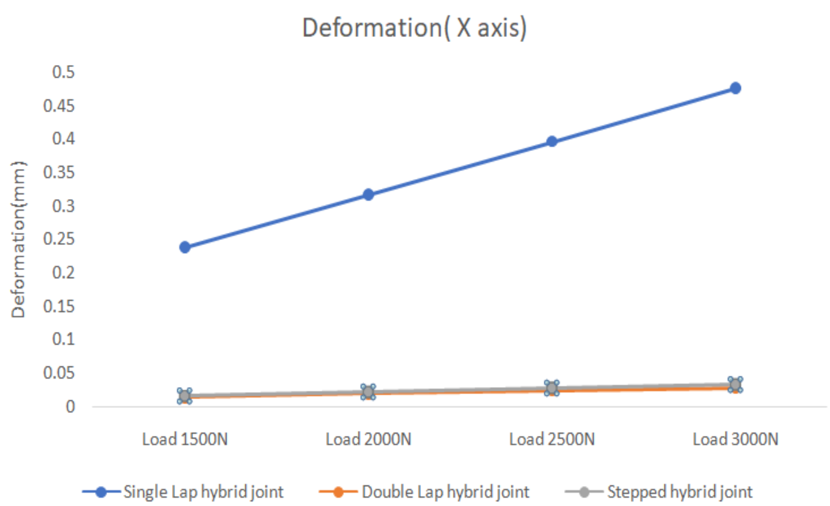

Fig.6 Graph between Deformation in X-axis & Loads acting on Single lap hybrid joint, Double lap hybrid joint and stepped hybrid joint.

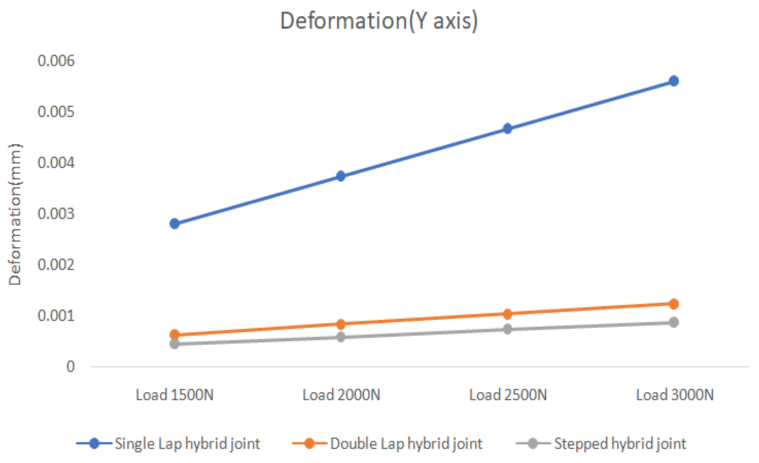

Fig. 7 Graph between Deformation in Y-axis & Loads acting on Single lap hybrid joint, Double lap hybrid joint and stepped hybrid joint.

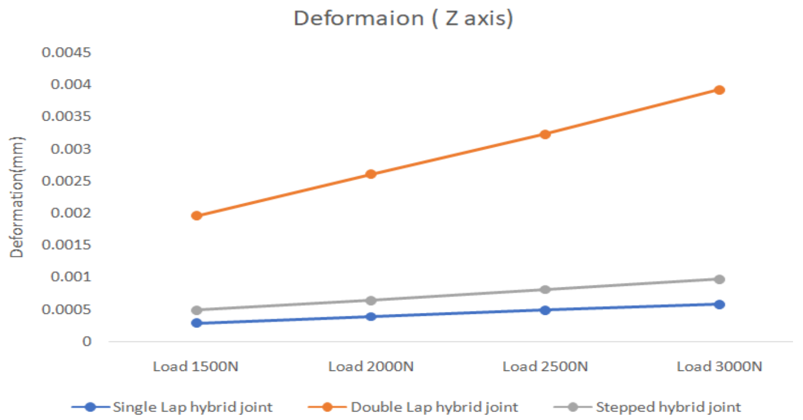

Fig.8 Graph between Deformation in Z-axis & Loads acting on Single lap hybrid joint, Double lap hybrid joint, and stepped hybrid joint.

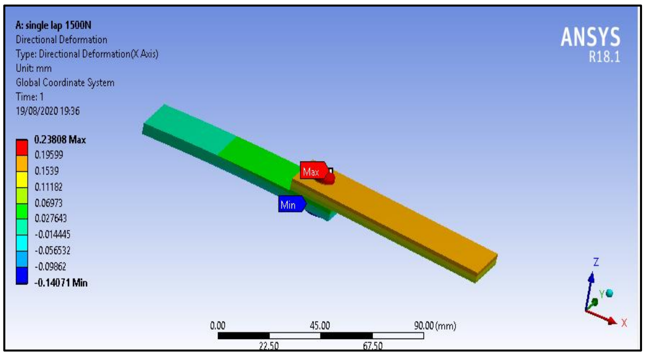

Fig.9 Deformation in Single lap hybrid joint in X-axis at load 1500 N

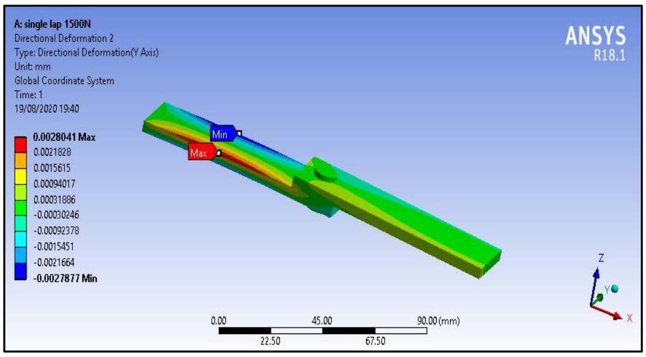

Fig. 10 Deformation in Single lap hybrid joint in Y-axis at load 1500 N

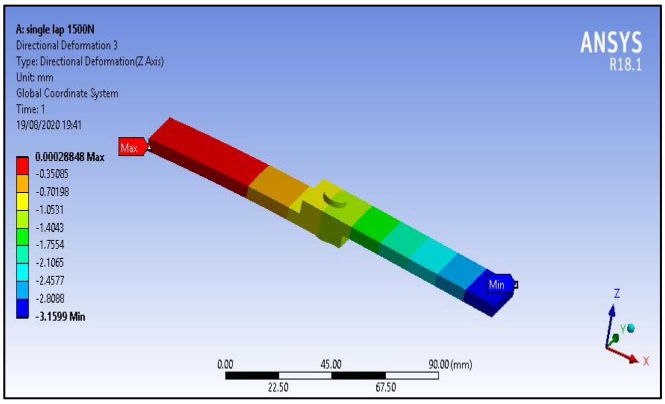

Fig.11 Deformation in Single lap hybrid joint in Z-axis at load 1500 N

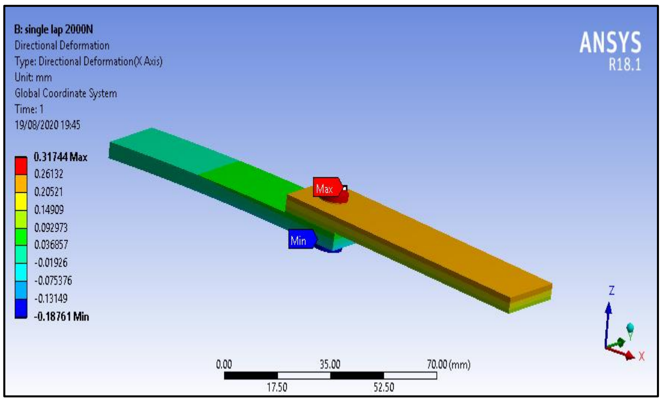

Fig. 12 Deformation in Single lap hybrid joint in X-axis at load 2000 N

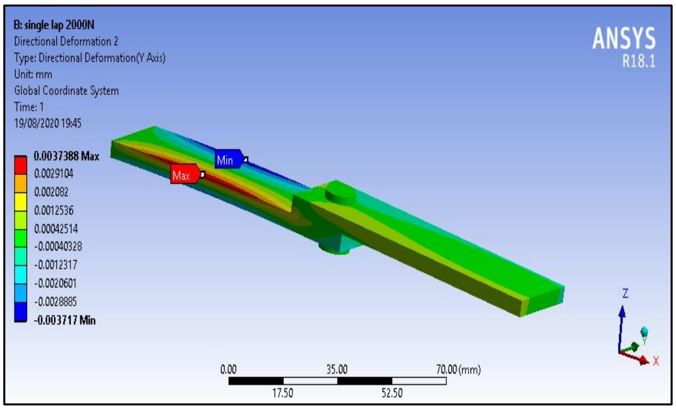

Fig.13 Deformation in Single lap hybrid joint in Y-axis at load 2000 N

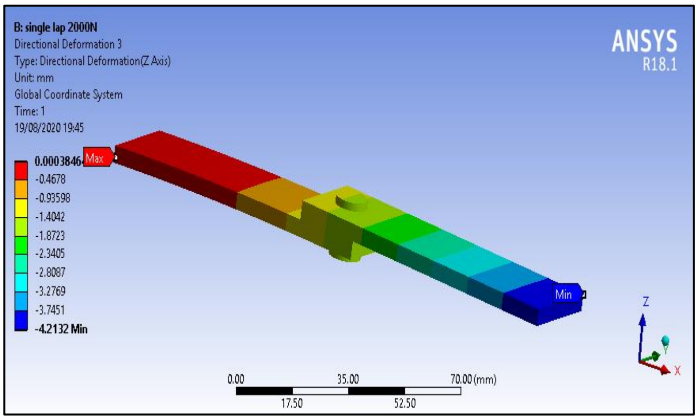

Fig.14 Deformation in Single lap hybrid joint in Z-axis at load 2000N

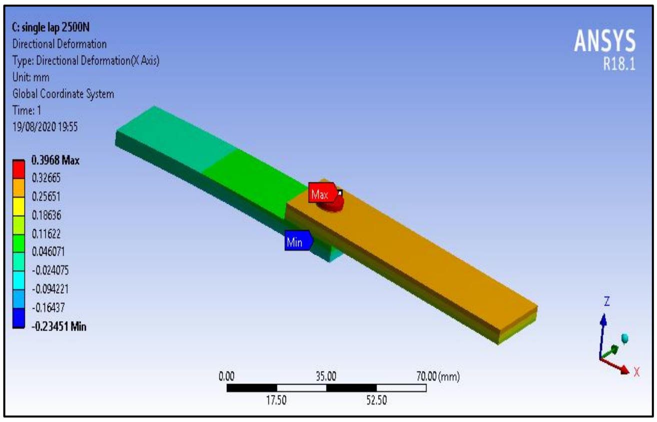

Fig.15 Deformation in Single lap hybrid joint in X-axis at load 2500N

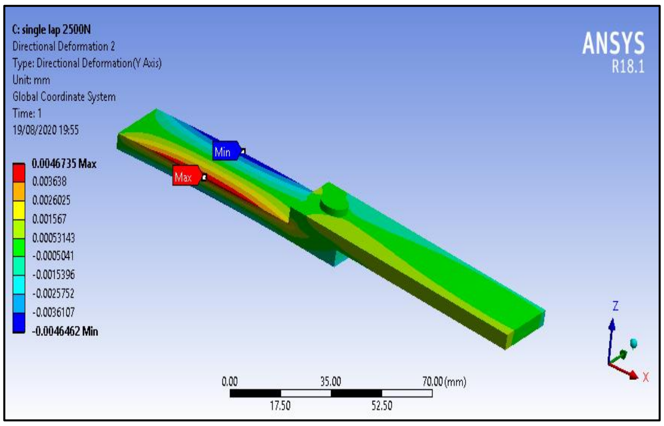

Fig.16 Deformation in Single lap hybrid joint in Y-axis at load 2500 N

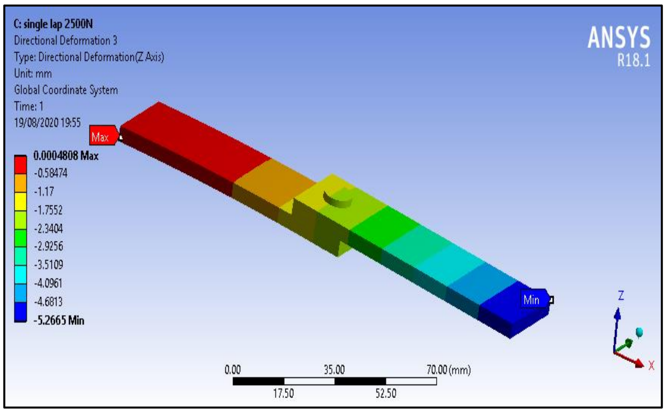

Fig.17 Deformation in Single lap hybrid joint in Z-axis at load 2500N

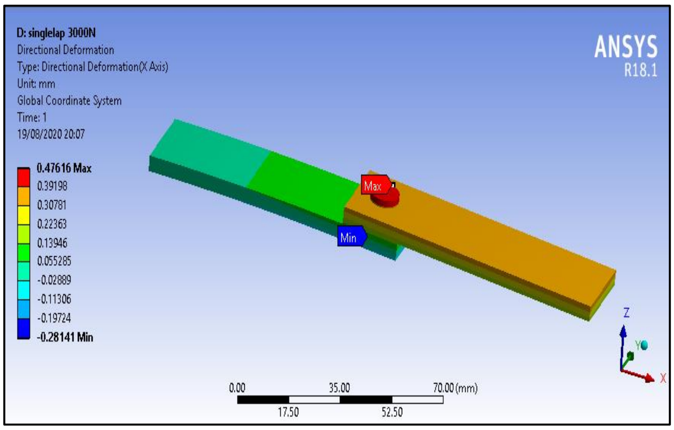

Fig.18 Deformation in Single lap hybrid joint in X-axis at load 3000 N

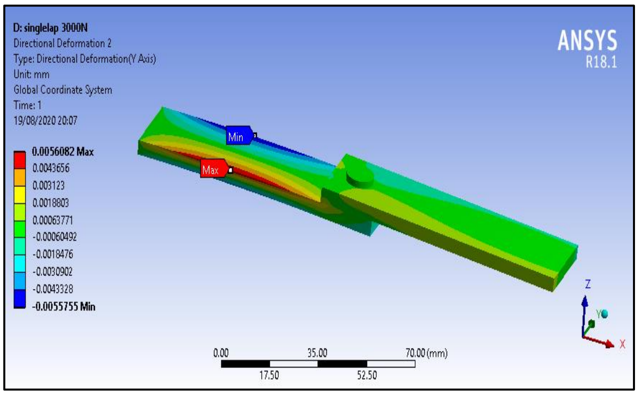

Fig.19 Deformation in Single lap hybrid joint in Y-axis at load 3000 N

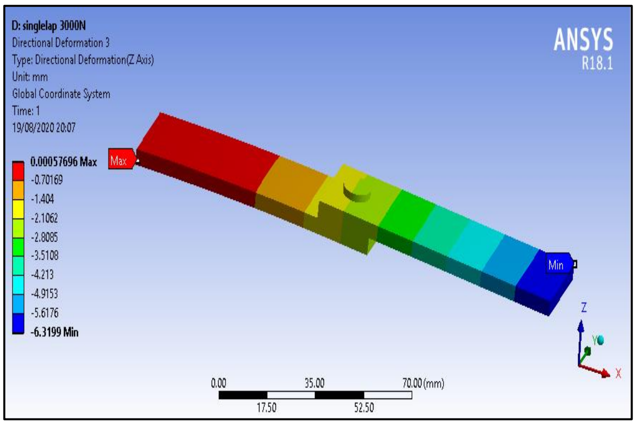

Fig.20 Deformation in Single lap hybrid joint in Z-axis at load 3000 N

The normal deformations of the single-lap hybrid composite joint are computed for various loads (1500 N, 2000 N, 2500 N, and 3000 N) in each direction. The analysis reveals that as the applied load increases, both the stresses and deformations continuously escalate in the single-lap hybrid composite joint.

Conclusion:

The analysis shows that deformation in the X-axis varies from 0.25 mm to 0.45 mm, in Y-Axis varies from 0.003 to 0.006 mm, and in Z- Axis varies from 0.002 to 0.004 in the case of a single Lap joint. Maximum deformation is observed in the X direction and the least in the Z direction. Deformation in the Y-axis is comparatively Lower than in the X-axis and varies from 0.003 mm to 0.005 mm. The double lap joint and steeped joint deformation is comparatively less as compared to single lap in all directions.

Reference

1. E Armentani, F Laiso Numerical FEM Evaluation for the structural behaviour of a hybrid (bonded/bolted) single lap composite joint 2018.
2. F. Esmaeili , T.N. Chakherlou, M. Zehsaz Investigation of bolt clamping force on the fatigue life of double lap simple bolted and hybrid (bolted/bonded) joints via experimental and numerical analysis 2014.
3. Ioannis K. Giannopoulos, Damian Doroni-Dawes, Kyriakos I. Kourousis, Mehdi Yasaee Effects of bolt torque tightening on the strength and fatigue life of airframe FRP laminate bolted joints 2017.
4. E. Paroissiena, F. Lachauda, S. Schwartz, A. Da Veiga, P. Barrière Simplified stress analysis of hybrid (bolted/bonded) joints 2017.
5. Shashikant Dashore, Mr. M. J. Patil, Dr. B. B. Ahuja Load Distribution in Hybrid (Adhesive & Bolted) Joint 2016.
6. B. Meganathan & E.S.Esakki raj Analysing The Composite Structure Of Riverted, Hybrid And Bonded Joints 2015.

7. Nguyen Duc Hai, Hiroshi Mutsuyoshi Structural behavior of double-lap joints of steel splice plates bolted/bonded to pultruded hybrid CFRP/GFRP laminates 2011.
8. Christophe Bois, Hervé Wargnier, Jean-Christophe Wahl, Erwann Le Goff An analytical model for the strength prediction of hybrid (bolted/bonded) composite joints 2012.
9. G. Marannano, B. Zuccarello Numerical experimental analysis of hybrid double lap aluminum- CFRP joints 2015.
10. M. Mariama, M. Afendia*, M.S. Abdul Majid Tensile and fatigue properties of single lap joints of aluminium alloy/glass fibrereinforced composites fabricated with different joining methods 2018.
11. Ryosuke Matsuzaki , Motoko Shibata Improving performance of GFRP/aluminum single lap jointsusing bolted/co-cured hybrid method 2008.
12. Gordon Kelly Quasi-static strength and fatigue life of hybrid(bonded/bolted) composite single-lap joints 2006.
13. Diana S.E. Abdelkerim, Xin Wang Static and fatigue behavior of pultruded FRP multi-bolted joints with basalt FRPand hybrid steel-FRP bolts 2019.
14. Xiaocong He, A review of finite element analysis of adhesively bonded joints, International Journal of Adhesion & Adhesives 31 (2011) 248–264
15. M D Banea1 and L F M da Silva2, adhesively bonded joints in composite materials: an overview, Proc. IMechE Vol. 223 Part L: J. Materials: Design and Applications
16. Xiang-fa Wu, Youhao Zhao, Stress-function variational method for interfacial stress analysis of adhesively bonded joints, International Journal of Solids and Structures, December 2013