Thin Walled Structures

Design and analysis of a composite T-joint used in automobile chassis

Dr. J.Anjaneyulu [a1],Niharika Kaza[b], Prajwala Gavuji[c]

Abstract:
This paper focuses on the analysis of composite T-joints which are used in automobiles under various loads, for both symmetric and anti-symmetric laminates. It is modeled analyzed using NX 11.0 and ANYSYS software's respectively. A composite is composed of a high performance fiber in a matrix material that when combined provides enhanced properties compared with individual materials. The main objective to use a T- joint made of composite like CFRP (Carbon fiber reinforced composite) is to achieve a car body design of light weight by which the fuel efficiency increases, both of which are primary considerations these days. Generally, we use conventional materials such as steel, aluminum etc. but because of favorable properties of composites such as improved torsional rigidity and impact properties, higher fatigue endurance limit, high durability, they are used extensively. The analysis results are presented for different design parameters.

Keywords*:* ANSYS; CFRP; Epoxy; FEA; Minitab; NX; Symmetric and Asymmetric orientations; T-joint

1. Introduction:

The T – joint is the connection between the B-pillar and the longitudinal rocker in an automobile as shown in Fig.1. It plays an important role not only in weight reduction but also in improving vehicle stiffness during side impact and rollover accidents thereby increasing the safety. There are a number of studies about the design optimizations of T-joint in automobile. Wenbin Hou [1] proposed a multi objective and multi constraint method for hat shaped composite T-joint, which is applied to the optimization of FEA results of T- joint, for traverse bending peak load, stiffness and mass. The non- dominated sorting genetic algorithm-II (NSGA-II) was used for optimal solution, and radial basis function (RBF) approximations objective functions to reduce computational costs. Xianzhe Xu [2] propounded bending behavior of a composite T -joint under out-of-plane loading for light weight automobile structure. These results show that composite T- joint is mainly influenced by the material properties and manufacturing processes, due to the fact that resin contained in the specimen cannot be controlled immediately during fabrication. Also it can be inferred that manufacturing process affects load carrying capacity and failure modes of T- joints.
The development of light weight vehicles is an increasing need due to the excessive consumption of fuel.
Burns et al. [3] researched about the influencing factors for radius bend region of a T-joint made of CFRP in bending and tensile tests. They found that the inter laminar tensile and shear stresses have relationship with ply orientation, hygro-thermal stability, and mid-plane symmetry. Burns et al. used bio-inspired design strategy to minimize the inter laminar stress concentration in the T-joint radius bend and to increase tensile strength while maintaining similar global laminate stiffness properties by optimizing ply angles and embedding the stiffener flange into skin plies.
This paper presents the analysis of deformed structures when load is applied and the parameters which vary accordingly.

ISSN 2229-5518

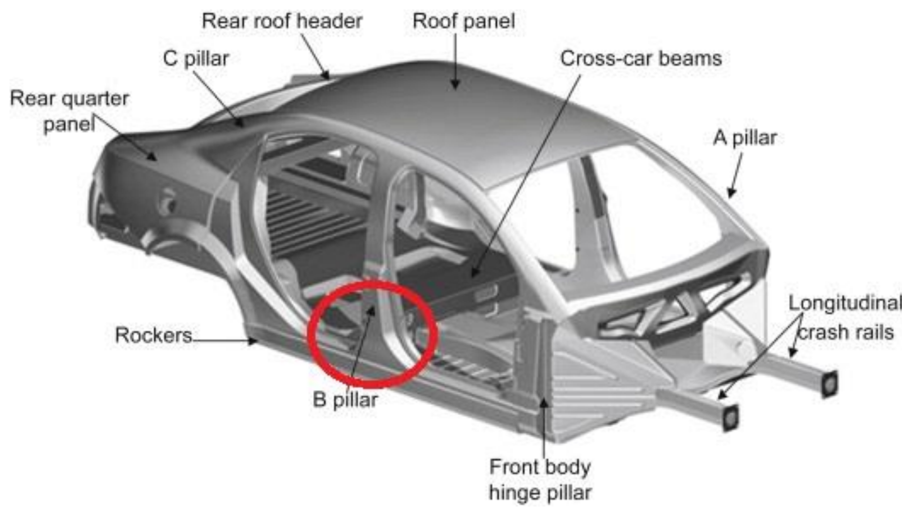


Fig 1: An illustration of a T-joint

2. Design of the T-joint:

Fig.2 shows the T-joint, which is a typical and key structural intersection between the B-pillar and the longitudinal rocker used in automobiles. When subject to a side impact, the T-joint could be subjected to an out-of-plane loading. In this study, only a quasi-static loading is considered.

The required dimensions are given and different models are designed using NX software. Different parameters are varied to know the result effectively. We have considered 5 models (Model-A to Model-E) by varying five parameters.

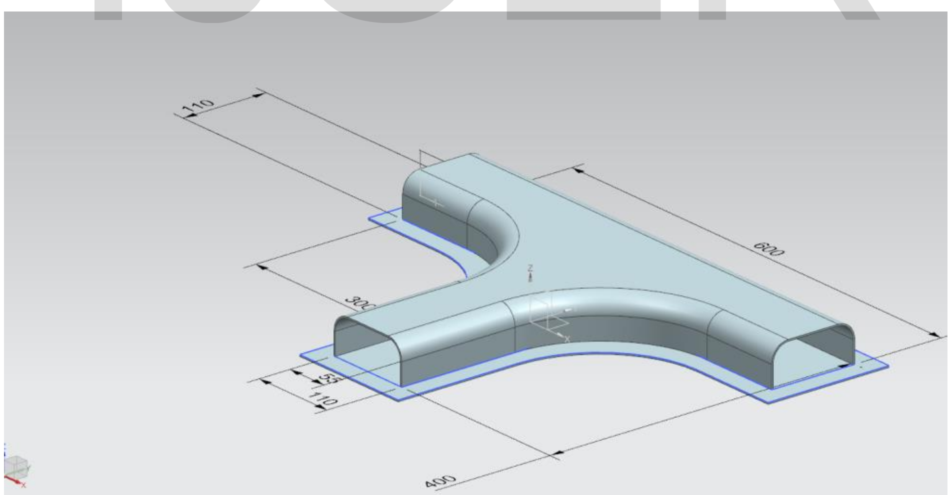


Fig 2: Schematic of the T- joint (NX model)

i. Nomenclature of the parameters used:

In this paper the design parameters include the fillet radius R, height of tube cross section H, width of cross section in B-pillar A, the width of cross section in longitudinal rocker direction B, radius of cross section r, width of overlap t, and number of plies for C-shaped shell and panel N_1, N_2 where N_1 is the number of plies for symmetric orientation of layers and N_2 is the number of plies for anti-symmetric orientation of layers. The ranges for these parameters are:

ISSN 2229-5518

100≤R≤140 40≤H≤55
80≤A≤120 80≤B≤120
15≤r≤25 10≤t≤30
6≤ N≤8 $6 \le N_1 \le 8$
F≥4514.4

Table A. shows dimensions of designed models (in mm)

Figure	**R**	**H**	**A**	**B**	**r**	**t**
Model A	100	40	80	80	15	10
Model B	110	45	90	90	16	15
Model C	120	50	100	100	20	20
Model D	130	50	110	110	22	25
Model E	140	55	120	120	25	30

The T-joint section is clamped at both ends of the rocker segment and subjected to an out-of-plane load at the end of the pillar segment. In the above models, the design parameters are varied within the given ranges.

3. Analysis of the T-joint:

All the models designed using NX for considered five models. The structural analysis of T-joint is carried out as per the following using ANSYS APDL software:
Type of Analysis: Static structural
Element type considered: Shell 3D 4node 181(as shown in Fig.3). It is a 4 noded element with 6 degrees of freedom at each node, which can be used for analyzing thin to moderately thick structures.
Material properties: The linear orthotropic materials are assigned as given in Table-B.
Boundary conditions: At both ends of Top flange of T-joint are fixed in all degrees of freedom.
Load application: As the side impact is the critical load for the T-joint, a transverse load (1000 N to 4500 N) is applied at bottom of the T-joint.

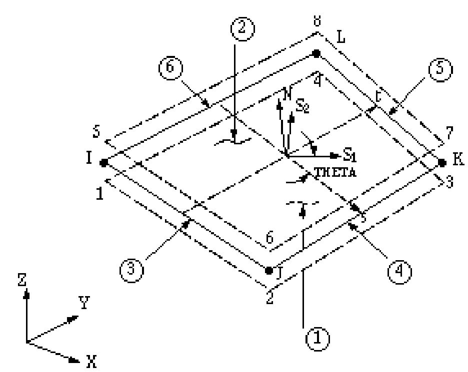


Fig 3: SHELL 181Element type in ANSYS

Table B. Material properties of carbon fiber and epoxy composite

Material property	**Value**
Density	1760kg/m^3
Young's modulus in X direction (N/m^2)	118e09
Young's modulus in Y direction (N/m^2)	7.8e09

ISSN 2229-5518

Young's modulus in Z direction (N/m^2)	7.8e09
Poisson's ratio	0.29
Shear modulus along X direction (N/m^2)	2.8e09
Shear modulus along Y direction (N/m^2)	2.7e09
Shear modulus along Z direction (N/m^2)	2.8e09

4. Results and discussions:

For an impact load of 1500 N, it is considered an equivalent static load of 3000N (twice of dynamic load value), the T- joint is analysed and the resultant displacement is shown in the Fig 4.

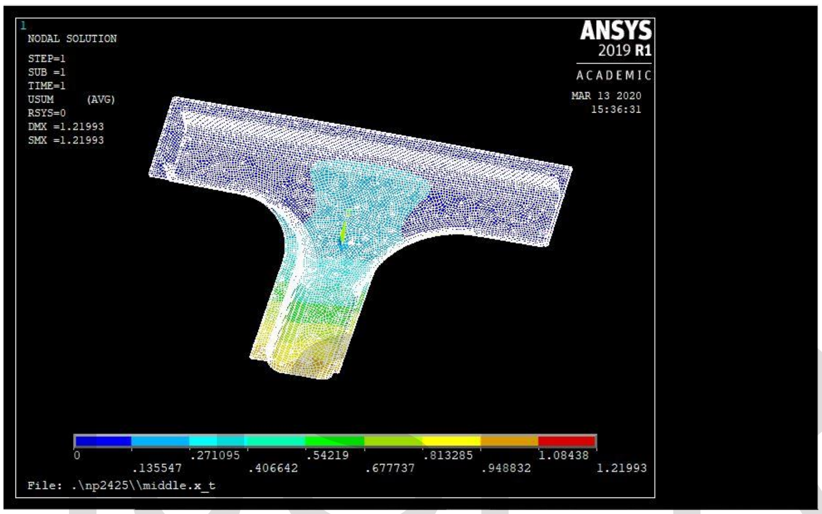


Fig 4: Displacement plot in ANSYS

A laminate is said to be symmetric if ply orientations are balanced about mid plane of laminate. A laminate is said to be anti-symmetric when symmetrically located layers have mutually reversed orientation. T he symmetric laminates has maximum bending and zero coupling stiffness coefficients. For anti-symmetric laminates they have pronounced coupling that can be important to resist twisting and bending. The aanalysis is carried for 4 ply laminate of symmetric (0˚, 90˚, 90˚, 0˚) and anti-symmetric (0˚, 90˚, 0˚, 90˚) and the results of load versus displacement are shown in Figs-5 and 6.

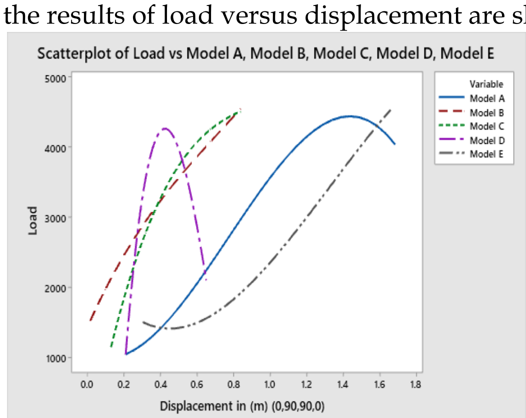


Fig 5: Symmetric orientation

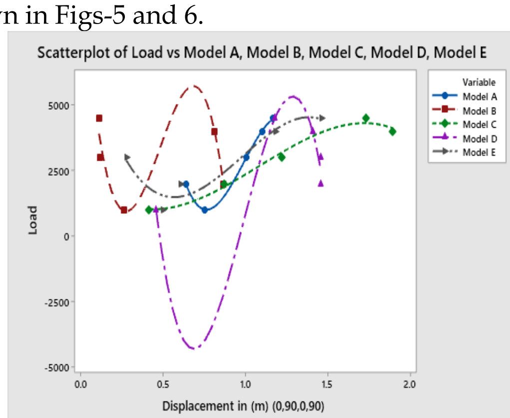


Fig 6: Anti-symmetric orientation

From the graph we can conclude that taking anti-symmetric orientation is more advantageous than symmetric for this application of transverse load. The graphs are plotted by taking corresponding values using Minitab software. The stiffness variation for five different models also shown in Fig 7.

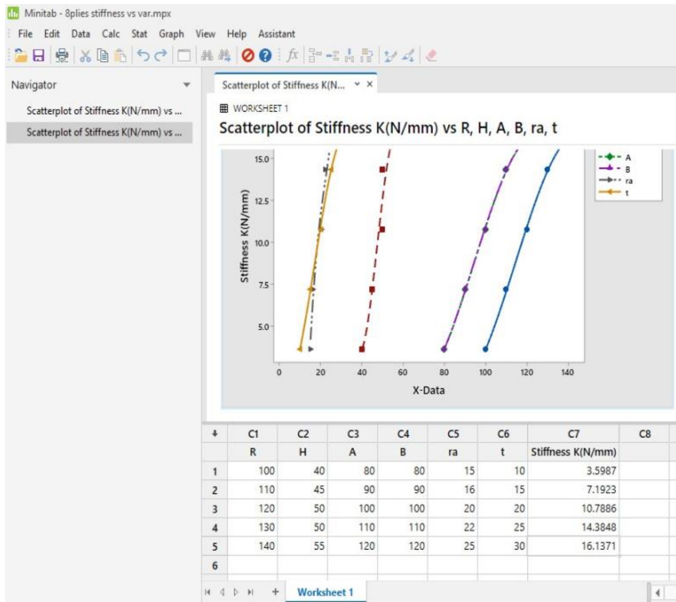


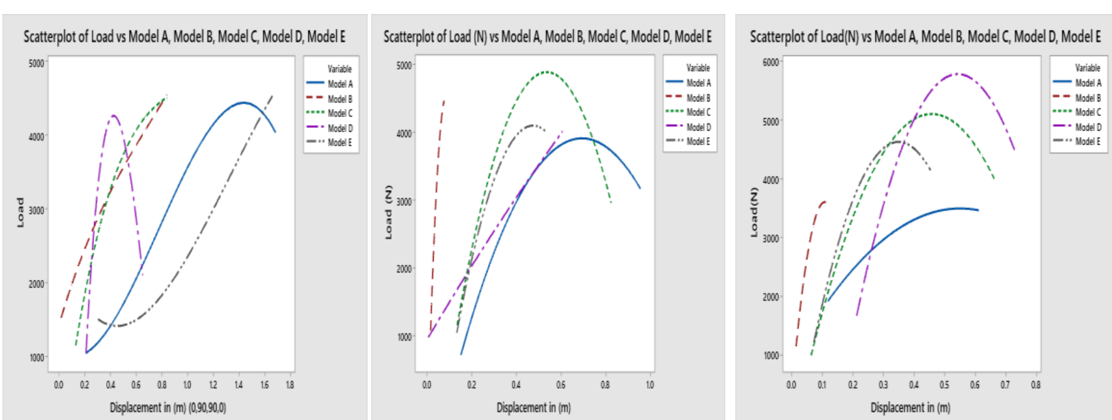
Fig 7: Minitab window showing values and graphs

The orientation of Anti-symmetric laminates with 4, 6 and 8 plies are shown in Table-C.

Table C:

Number of Plies	Orientation (Anti-Symmetric)
4	(0˚,90˚,0˚,90˚)
6	(0˚,90˚,0˚,0˚,90˚,0˚)
8	(0˚,90˚,0˚,90˚,0˚,90˚,0˚,90˚)

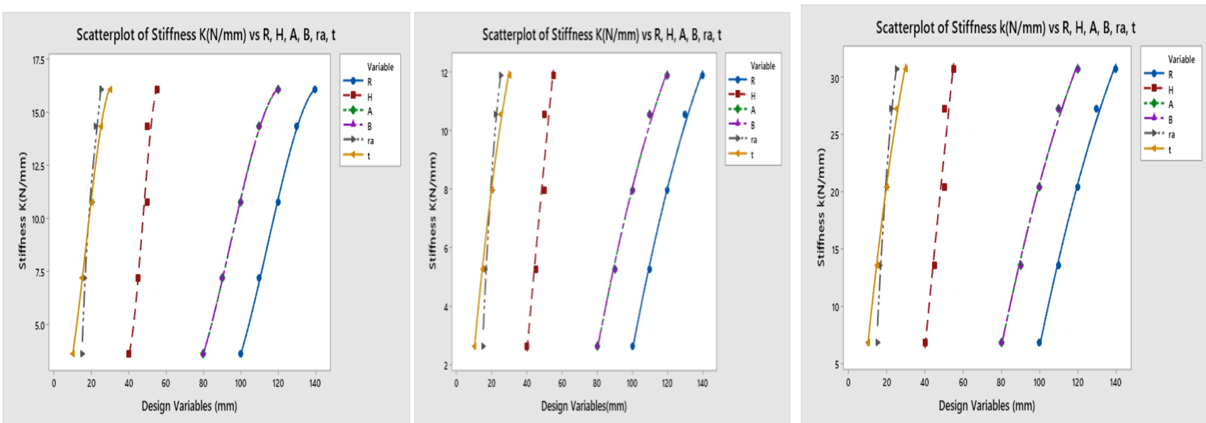
The change in number of plies lead to limited influence on structural performance as shown in Fig 8, but they are the light weight variable of the T-joint which is under consideration.



(a) 4 plies (b) 6 plies (c) 8 plies

Fig 8: Variation of load with displacement for (a) 4 plies (b) 6 plies (c) 8 plies

From Fig 9 below, it can be concluded that the improvement of variable R can increase the stiffness along with load. By increasing variables such as H, A, B and r, improvement in structural performance can be improved.

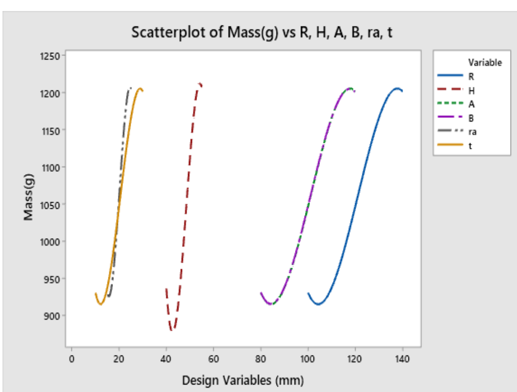


(a) 4 plies (b) 6 plies (c) 8 plies

Fig 9: Variation of stiffness with design variables for (a) 4 plies (b) 6 plies (c) 8 plies

A graph is also shown in Fig 10 which shows the variation of design variables with mass.

This mass is obtained with the volume of the model created using NX and density of the material considered (carbon fiber) which is 1760 g/cc



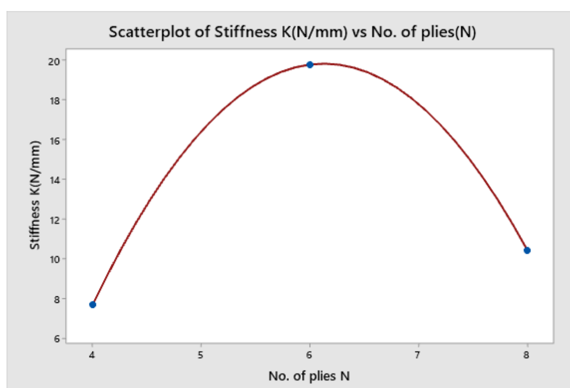


Fig 10: Mass versus design variables Fig 11: Variation of stiffness with number of plies

A parabolic variation can be observed in the graph (Fig 11) of stiffness versus number of plies. As the number of plies increases, the stiffness gradually decreases after increase of 6 plies. Hence a 6 ply laminate has better stiffness for this application. Also it is observed that the deflection decreases with increase in plies.

5. Conclusions and future scope:

The single hat-shaped T-joint, sectioned from the intersection between B- pillar and longitudinal rocker has been studied analytically. This work involves successful design of the T-joint and analysis using different loads and orientations. The anti-symmetric laminate showed better result for this application. The 6 ply laminate showed better stiffness out of 4, 6 and 8 ply laminates. This prudent analysis is required for the design of automobile chassis. Further, this analysis can be extended by including volume fraction of each lamina and dynamic analysis and crash analysis can be performed for more accurate results.

6. References:

[1] Wenbin Hou, Xianzhe Xu, Xiao Han, Haifeng Wang, Liyong Tong, Multi- objective and multi -constraint design optimization for hat shaped composite T-joints in automobiles, Thin walled structures 143 (2019).

[2] W. B. Hou, X. Z. Xu, H. F. Wang, L. Y. Tong. Bending behavior of single hat shaped composite T-joints under out-of- plane loading for light weight automobile structures, J. Reinf. Plast. Compos. 37(12) (2018) 808-823.

[3] Burns et al, The influencing factors for radius bend region of a T-joint made of CFRP in bending and tensile tests,2018.

[4] Z. Liu, J. H. Lu, P. Zhu, Lightweight design of automotive composite bumper system using modified particle swarm optimizer, Compos. Struct. 140 (2016) 630-643

[5] M. Tarfaoui, S. Choukri and A. Neme,"Effect of fibre orientation on mechanical properties of the laminated polymer composites subjected to out-of-plane high strain rate compressive loadings",Elsevier, 2007, 68 (2), pp.477. <10.1016/j.compscitech.2007.06.014.

[6] G. Belingardi, E. G. Korincho, B. Martorana, Design optimization and implementation of composite and recyclable thermoplastic materials for automotive bumper, Int. J. Automot. Compos. 1 (1) (2014).

[7] Q. Liu, Y. Lina, Z. Zonga, G. Sun, Q. Lic, Lightweight design of carbon twill weave fabric composite body structure for electric vehicle, Comps. Struct. 97 (2013) 231-238.

[8] A. Gliszczynski, T. Kubiak, Load carrying capacity of thin walled composite beams subjected to pure bending, Thin walled struct. 115 (2015) 76-85

[9] Amanda J. Carbon fibre and cars-2013 in review. Reinf Plast Compos 2014; 58: 18–19.

[10] Jambor A and Beyer M. New cars-new materials. MaterDes 1997; 18: 203–209.

[11] Koricho EG and Belingardi G. An experimental and finite element study of the transverse bending behavior of CFRP composite T-joints in vehicle structures.Compos Part B: Eng 2015; 79: 430–443.

Corresponding author [a1]**: J.**Anjaneyulu. J, Sr.Asst. Professor, Department of Mechanical Engineering, Vasavi College of Engineering, Hyderabad, Telangana. E-mail: anjaneyulu_jalleda@yahoo.co.in. [b,c]: Students, BE Mech.Engg, VI Sem. Vasavi College of Engineering, Hyderabad, Telangana