Finite Element Analysis of Composite Wing T-Joint

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ABSTRACT:

Advanced composites are widely being used in aerospace and other structural applications due to their quality features like light weight, high stiffness, high strength, corrosive resistance and design tailor ability etc. The above features attract the research community to work in this area. In the present project work, a vital component in the design of aircraft wing T-joint is considered for the analysis using finite element method. The T-joint is modeled with solid-46 element using ANSYS software, since the geometry is complex. The model is having the stacking sequence of [(±45)4/(∓45)4] for the web with thickness 3.6mm. The flange consists of one-half of the web plus a [((±45)6)s] laminate from the bottom, that makes a flange lay up of [(±45)4/((∓45)4)s] on one side and [(±45)4/((∓45)4)s] on the other side.

Static analysis being attempted in this work. In, the static analysis, response and initiation of failure of the T-joint are studied under pull load. The initiation of failure is estimated using polynomial interaction Tsai-Wu criterion is implemented. The generated numerical results were presented in the form of figures and tables. It is noticed that the failure will occur in the web/flange junction of the T-joint.

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INTRODUCTION

Aircraft wing T-joints made up of composite materials are special importance due to complex geometry and criticality to overall structural integrity. The T-joints often fail due to transverse normal and shear stresses, because the absence of fibers oriented normal to the plane of laminate results in resin-dominated low interlaminar strength properties. As a results, the out of plane strength of T-joint is severely, limited by the interlaminar strength of the constituent laminates. The out of plane force results in interlaminar normal stress (σz), interlaminar shear stresses (τyz and τxz) and in-plane stress (σy), which influence the failure patterns of T-joints.

It has been reported that the composite T-joints often fail near the web skin interface due to transverse normal stresses. Therefore, to predict the failure more precisely it is necessary to develop a means of computing the magnitude of these transverse, normal stress components at the web/skin interface as accurately as possible. For finding the transverse stress components, a three dimensional formulation is needed. The weak interlaminar strength properties can cause examination and failures in local area of stress concentration. Under the static loading transverse normal stresses are critical in web/skin interface as it may cause failure initiation.

ANALYTICAL SUPPORT

A Graphite/epoxy T-joint specimen is considered for the numerical investigation. The typical T-joint is as shown in fig 3 and the specimen dimensions are W=116mm, H=75mm, and L=80mm, web thickness (tw) =3.6mm, outer radius at the web/skin interface is 5.5mm and skin thickness are 3.6mm.

The stacking sequence for the web (3.6mm thick) for all specimens consists of a [(±45)4/(∓45)4] laminate. For the series of the specimen the flange consists of one-half of the web plus a [((±45)6)s]laminate from the bottom, that makes a flange lay up of [(±45)4/((∓45)4)s] on one side and [(±45)4/((∓45)4)s] on the other side.

6 LAMINA (AS4/3501) MATERIAL PROPERTIES

E11	136.4Gpa
E22	8.90Gpa
E33	8.90Gpa
G12	5.95Gpa
G23	3.21Gpa
ϑ12	0.25
ϑ23	0.38

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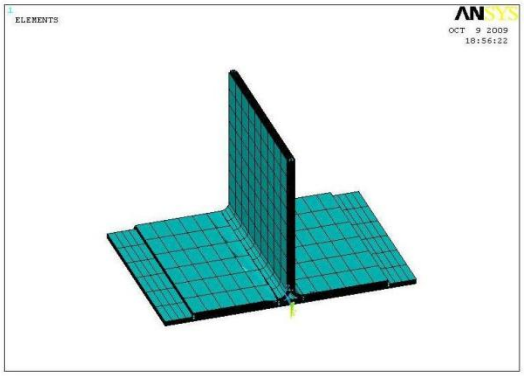
ANALYTICAL INFORMATION OF COMPOSITE T-JOINT:



STATIC ANALYSIS

The term “static” means that the forced do not vary with time or, that the time variation is insignificant and can therefore be safely ignored. A static analysis calculates the effects of steady loading conditions on a structure, while ignoring inertia and dumping effects, such as those caused by time varying loads. A static analysis can, however, include steady inertia loads (such as gravity and rotational velocity), and time-varying loads that can be approximated as static equivalent loads.

Static analysis is used to determine the displacements, stress, strains and forces in structures or components caused by loads that do not induce significant inertia and damping effects. Steady loading and response conditions are assumed; that is, the loads and the structure’s response are assumed to vary slowly with respect to time. The kinds of loading that can be applied in the static analysis include: Externally applied and pressures Steady- state inertia forces (such as gravity or rotation velocity) Imposed (non zero) displacements Temperatures (for thermal strains)

The static analysis equation is,{k} {u} ={f}

Where ‘K’ is the system stiffness matrix (generated automatically by ANSYS for windows, based on the geometry and properties),’f’ is the vector of applied forces (which you specify), and u is the vector of displacements that ANSYS computes. Once the displacements are computed, ANSYS uses these to compute element forces, stresses, reaction forces and strains.

OVERVIEW OF STEPS IN STATIC ANALYSIS

The procedure for a static analysis consists of three main steps:

I.Build the model:

To build the model, define the element type, element Cross-sectional properties, and material properties and build the model using the model geometry.

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Apply loads & obtain the solution In this step, define the analysis type & options, apply loads, specify load options and begin the finite elements solutions. Mesh the model and apply loads, and constraints Enter the ANSYS solution processor. Define the analysis type in analysis option. Specify load set and constraint set in solution. Solve for the results using the ANSYS solver. Obtain the finite solution.

II. REVIEW RESULTS:

Two types of results from the static analysis can be written to the structural results file. They are Primary Data:

Nodal displacements (U_X, UY, UZ, ROTX, ROTY, ROTZ)

III. **Derived Data:**

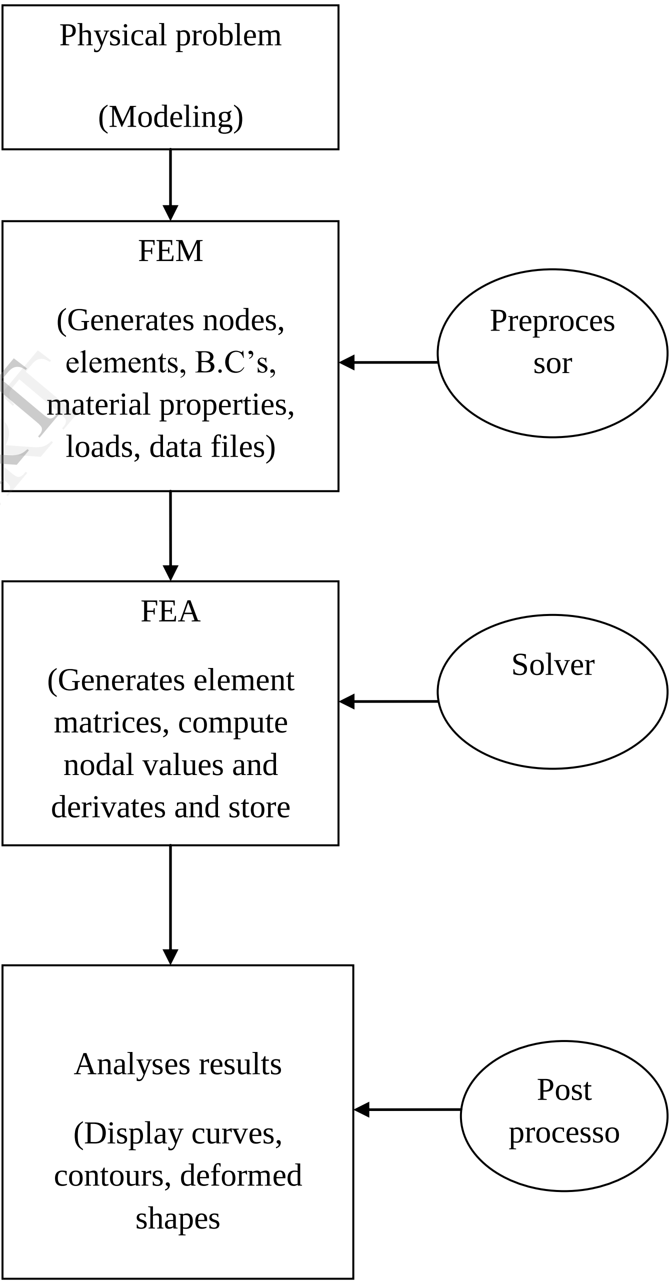
Nodal & elemental stress

Nodal & elemental strain

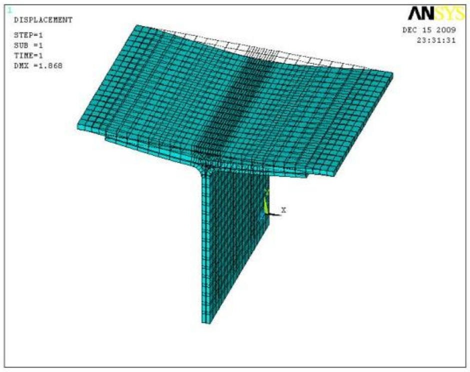
Axial/ Elemental forces

Nodal reaction forces etc.

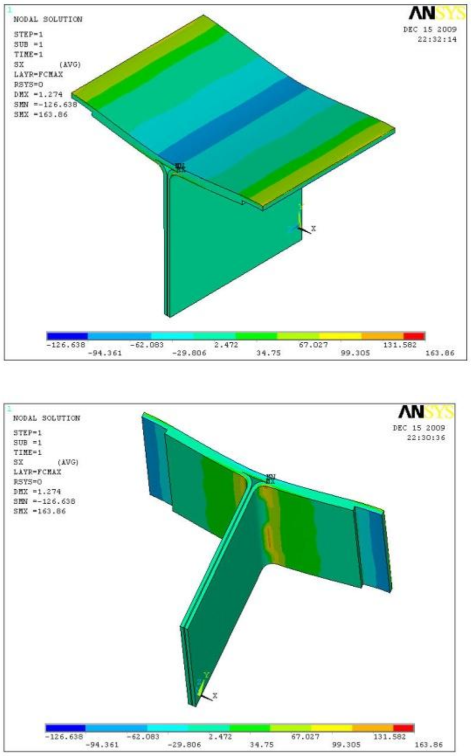
FEA PROCESSOR



Static load applied as 750, 1000, 1100, and 1200N: After completion of doing modeling of composite layered T-joints as numerical values are given, and used ANSYS to determine the stresses and deformations under static loading as 750, 1000, 1100, 1200N. The layered results (stresses and strains) and deformations as well as results are mentioned.



Deformed shape under static loading as 1100N.



Stress values in x-direction at static load 750N.

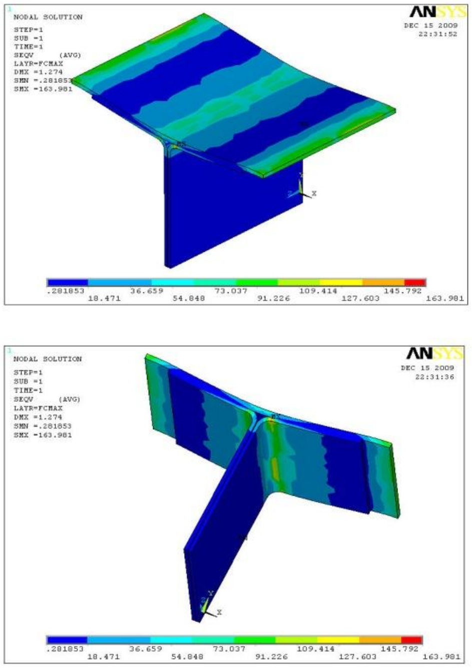


Fig.9 Von-Mises stress distribution at static load 750N.

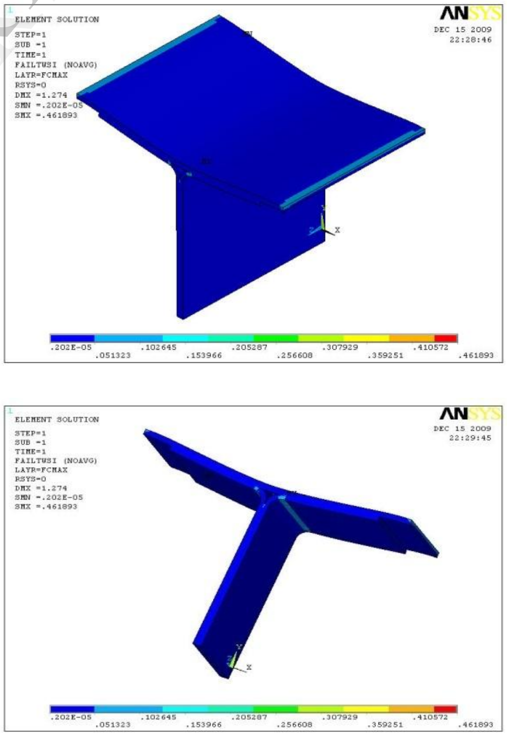


Fig.10 Tsai-Wu failure index at static load 750N.

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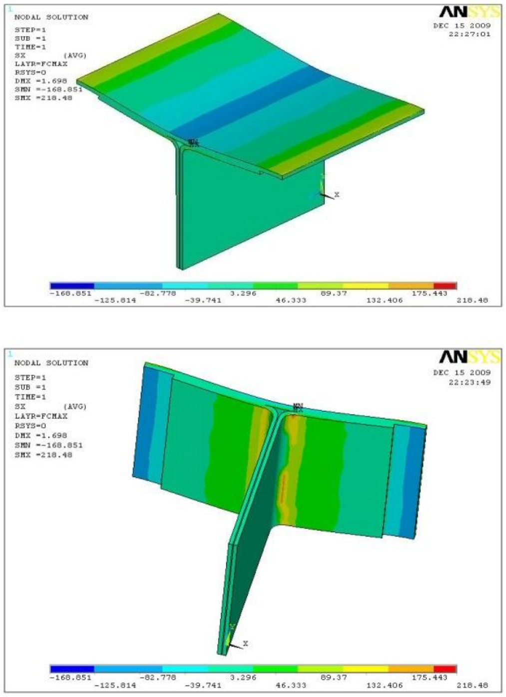

Fig.11 Stress values in x-direction at static load 1000N.

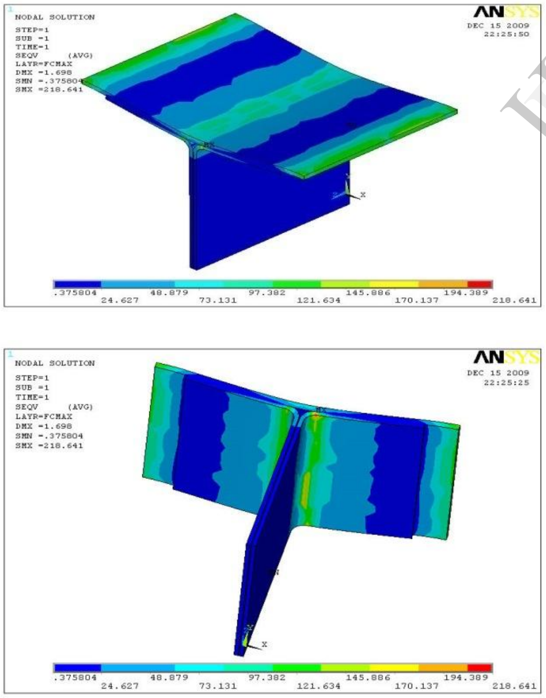

Fig.12 Von-Mises stress distribution at static load 1000N**.**

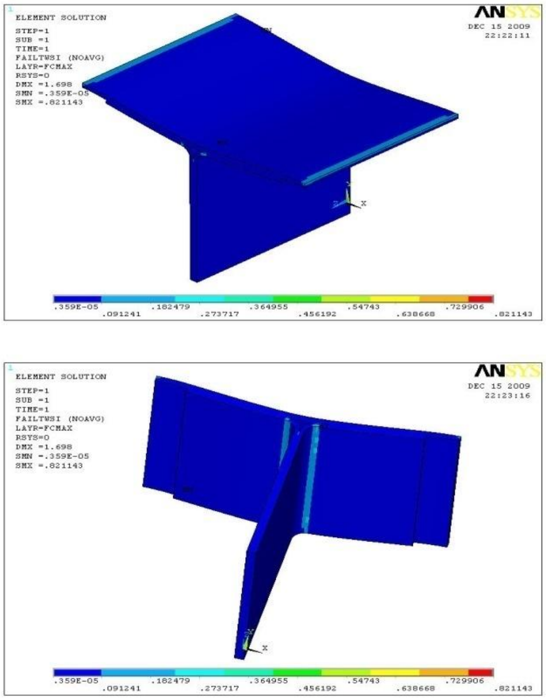

Fig.13 Tsai-Wu failure index at static load 1000N

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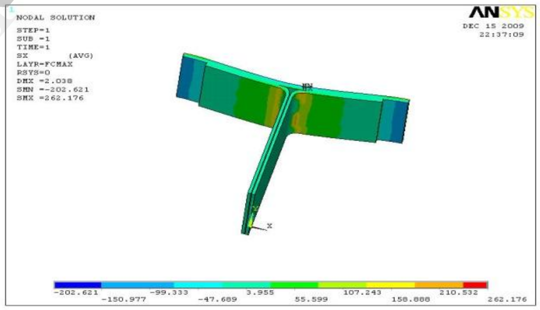
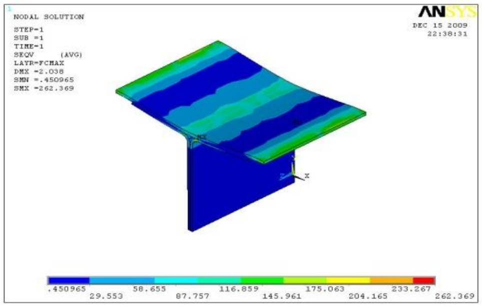


Fig.17 Stress values in x-direction at static load 1200N.



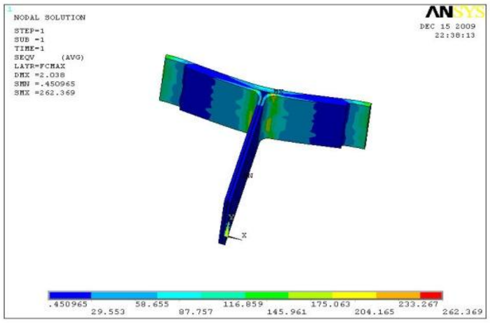


Fig.18 Von-Mises stress distribution at static load 1200N.

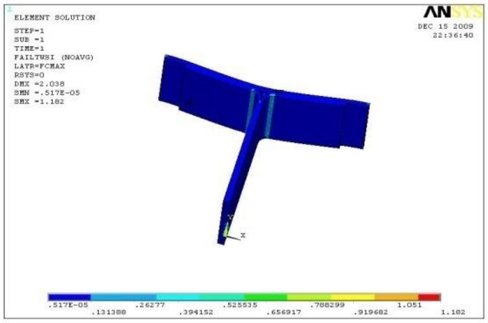


Fig.19 Tsai-Wu failure index at static load 1200N.

RESULTS: Table.2 Load-failure index results

APPLIED LOAD (Newtons)	MAX STRESS IN X-DIRECTION (N/mm^2)	MAX STRESS IN VON-MISES STRESS CRITERION (N/mm^2)	MAX STRESS INDEX (Tsai-Wu FAILURE CRITERION)
750	163.86	163.981	0.4618 (safe)
1000	218.48	218.641	0.82114(safe)
1100	240.328	240.505	0.9935(safe)
1200	262.176	262.369	1.182(un safe)

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The static response of the composite wing T-joint is analyzed by using ANSYS software. Also predicted the loads for initiation of failure is obtained using polynomial interaction Tsai-Wu failure criterion. In the composite wing T-joints web-flange junction may be the failure zone due to complexity in geometry. The bending behavior of the joint is obtained for different pull loads such as 750, 100, 1100, and 1200 N and the results tabulated in the table 2. It is observed from the results the failure is initiated at web-flange junction for the load 1200 N. Also noticed that the failure caused due to the maximum stress is 262.176 $^{N}/_{mm^2}$ and maximum Von-Mises stress is 262.369 $^{N}/_{mm^2}$.

In first load case (750N) the maximum stress induced in the composite component is 163.86MPa. In Von-Mises criterion the maximum stress induced in the composite wing T-joint is 163.981MPa. And according to Tsai-Wu failure index, the maximum stress index is 0.461. This value is less than 1. So the component is safe.

In second load case (1000N) the maximum stress induced in the composite component is 218.48mpa. In Von-Mises criterion the maximum stress induced in the composite wing T-joint is 218.641MPa. And according to Tsai-Wu failure index, the maximum stress index is 0.8211. This value is also less than 1. So the component is safe.

In third load case (1100N) the maximum stress induced in the composite component is 240.328 MPa. In Von-Mises criterion the maximum stress induced in the composite wing T-joint is 240.505 MPa. And according to Tsai-Wu failure index, the maximum stress index is 0.9935. Which is less than the value 1.So the component is safe.

In fourth load case (1200N) the maximum stress induced in the composite component is 262.176MPa. In Von-Mises criterion the maximum stress induced in the composite wing T-joint is 262.369 MPa. And according to Tsai-Wu failure index, the maximum stress index is 1.182. The failure index value violates the condition of failure. Therefore 1200 N may be the initiation failure load.

CONCLUSIONS

The interface zone between the web and the flange near the filler area introduces geometrical and material discontinuities and is usually the critical zone for failure initiation.

It is observed that first crack occurs at the web/skin interface either in web element or in skin element due to inter-laminar transverse normal and shear stresses.

The Tsai-Wu failure criterion is implemented to check the initiation of failure and mode of failure. It is observed from the results. Failure initiated due to normal stress along the x-direction and also observed that the failure load is at 1200N.

To compute natural frequencies and mode shapes efficient subspace iteration method implemented.

The dynamic equation is solved using Newmark’s constant average acceleration technique. The response and the location of the maximum stresses are presented for two types of time dependent loads.

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REFERENCES:

1. Broutman, L.J. and Richard, H.K. 1967, "Modern composite materials", Addison-Wesley publishing company.
2. Fukuda, H., Tomatsu, H. and Yasuda, J.1995, "three-dimensional micromechanical approach to the strength of unidirectional composites", Computers and Structures, Vol.40.
3. Gillespie, J.W. Jr and Pipes, R.B. 1978, "Behavior of integral composite joints-finite element and experimental evaluation", Journal of Composite Materials Vol. 12.
4. John, C.B. and Paul, A.L.1988, "Quadratic stress criterion of initiation of delamination", Journal of Composite Materials, Vol. 22.
5. Rispler, A.R., Steven, G.P. and Tong, L. 1997, "Failure analysis of composite T-joints including inserts", Journal of reinforced plastics and Composites, Vol. 16.
6. Shenoi, R.A. Read, P.J.C.L. and Jackson, C.L. 1998, "Influence of joint geometry and load regimes on sandwich tee joint behavior", Journal of reinforced plastics and Composites, Vol. 17.
7. Syama, Kumari and Sinha, P.K. 2002, "Finite element analysis of wing T-joints", Journal of reinforced plastics and Composites, Vol. 21.
8. Stickler, P.B. and Ramulu, M. and Johnson, P.S. 2000, "Experimental and numerical analysis of transversed stitched T-joints in bending", Composite Structures, vol. 50.
9. Tsai, S.W. and Hahn, H.T. 1980, "Introduction to composite materials", Technomic, Westport, CT.
10. Tsai, S.W. and Wu, E.M. 1970, "A general theory of strength for anisotropic materials", Journal of Composite Materials, vol. 4.
11. Whitney, J.M. and Mc Coullough, R.L. 1990, "Macro mechanical material modeling", Lancanster Basel Technomic Publishing Co. Vol. 2.
12. Zeinckiwicz, O.C. and Taylor, R.L. 1991, "The finite element method", Geometrically Non-linear problems-large displacement and Structural instability, Vol. 2. McGraw-Hill, New Delhi.
13. Natural vibrations of laminated anisotropic plates by J. N. Reddy and T. Kuppusamy 1983.

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