iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 9 Issue: VI Month of publication: June 2021

DOI: https://doi.org/10.22214/ijraset.2021.34923

Computational Investigation of Square Embedded Delamination of a Composite Laminate using VCCT

K. S. Vishwanath
Assistant Professor, Department of Aerospace Engineering, IIAEM, Jain Deemed to be University, Bangalore-562112, Karnataka, India.

Abstract: The fiber reinforced polymer laminates are widely implemented in aviation industry due to its advantages and applications other materials in terms of strength to weight ratio, dsign features and many more. The strength of the interface compared to longitudinal and lateral directions of the plies are comparatively less and give rise too poor transverse direction strength. Hence a failure mechanism called delamination will occur in case when tools are dropped or due to poor manufacturing which would give rise to interface delamination. In this paper, VCCT is employed at the interface between base and sub laminate to investigate for a square shape delamination geometry of 20mm buckling driven delamination growth. The computational prediction of delamination growth initiation is obtained by solving a T300/976 specimen for geometric non linearity using SC8R continuum shell elements of Abaqus CAE and by plotting the required energy release rate at the delamination geometry.
Keywords: Square embedded delamination, VCCT, uniaxial compression, B-K criterion, energy release rate.

I. INTRODUCTION

The failure mechanisms of an FRP are fiber pullout, fiber bridging, matrix debonding, matrix cracking, delamination, micro buckling and kink bands. And the focus of this paper is on interface delamination due to uniaxial compressive loads. Delaminations are known to decrease the overall stability, stiffnes and strength of the specimen that reduces the load bearing capacity under compressive loads. The causes of delamination are Impact, In-service loads, Load generating transverse stresses, cut outs, notch, Material and structural discontinuities, bonded joints and plydrop. Relatively the interface is weaker in the transverse direction when compared to the strength of plies, which will lead to high transverse and normal stresses inducing interlaminar stresses that would lead to separation of layers. Hence it is necessary to predict the delamination initiation growth using damage tolerance technique by VCCT [1].

II. LITERATURE SURVEY

Initial works were done by Chai et al for 1D and 2D problems [2][3]. Whitcomb and Shivakumar examined the delamination growth due to the local buckling of a composite plate with square and rectangular embedded delaminations [1]. Nilsson et al. studied delamination buckling and growth of slender composite panels using both experimental and numerical methods [4]. Riccio et al. investigated the compressive behavior of carbon fiber/epoxy laminated composite panels containing through the width and embedded delaminations [5]. Lachaud et al. studied the VCC integral to investigate the propagation of delamination caused by the local buckling, on thermoplastic and thermoset carbon/ fiber composite laminates having embedded delaminations. They also conducted experimentations to verify the achieved outcomes from the simulation[6].

III. METHODOLOGY

The work is carried out by virtual crack closure technique (VCCT) whose theory is that the energy required for a crack in its existing configuration to its next arrangement and then next to its' extended formation is the same energy required to close the crack and bring it back to its initial configuration as shown in Fig 1and 2 [7]. This procedure is based on Irwin's crack closure method. The work ΔE required to close the crack along one element side can be calculated as

$$\mathbf{\Delta E = \frac{1}{2}[X1l.\,\Delta u_{2l} + Z1l.\,\Delta w_{2l}\,]}$$

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 9 Issue VI Jun 2021- Available at www.ijraset.com

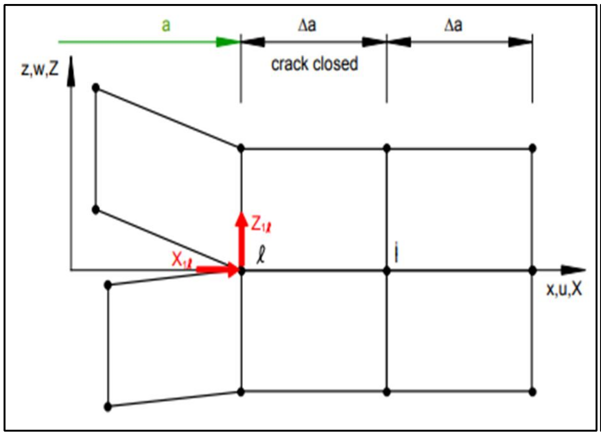


Fig 1: First step crack closed

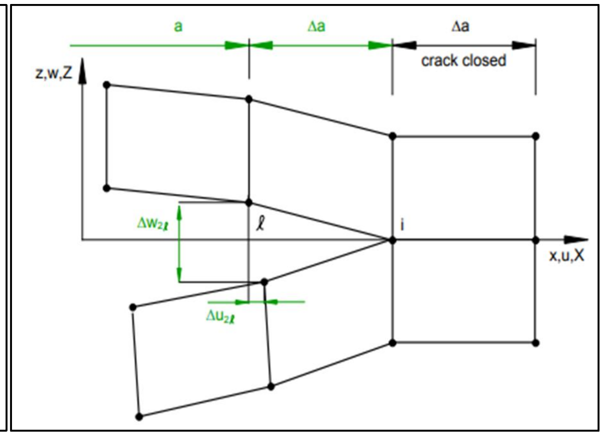


Fig 2: Second step crack extended

where X_{1l} and Z_{1l} are the shear and opening forces at nodal point l which gets closed and Δu_{2l} and Δw_{2l} are the shear and opening nodal movements at node l.
The energy release rate is calculated as $G=\Delta E/\Delta A$, where ΔA is the surface area of the newly formed crack extension.

For delamination growth initiation, Benezeggagh-Kenane criterion is applied [9].
In real time applications, delamination progress occurs due to energy release rates in all 3 directions namely normal and 2 shear directions. Hence total energy release rate is given by $G_T=G_I+G_{II}+G_{III}$ and the nodes open up and the damage propagates when the condition $G_T/G_C\geq 1$ is satisfied, where critical energy release rate is found by B-K criterion that has contribution from all 3 modes given by $G_C=G_{IC}+(G_{IIC}-G_{IC})(G_S/G_T)^{\eta}$, where $G_S=G_{II}+G_{III}$.

Now a specimen having unidirectional stacking sequence of $[0_4 / 0_{12} // 0_4]$ is considered which is made of the T300/976 as in [3]. The symbol // illustrates initial delamination geometry location in the material. The geometry of the case with single delamination is shown in the Fig. 1. The material properties of T300/976 are E_{11}=139300 (N/mm2), $E_{22}=E_{33}$=9720 (N/mm2), $G_{12}=G_{13}$=5580 (N/mm2), G_{23}=3450 (N/mm2), $\nu_{12}=\nu_{13}$=0.29, ν_{23}=0.4, G_{IC}=0.0876, G_{IIC}=0.3152 (N/mm), σ_o = 44.54 (N/mm2), τ_o = 106.9 (N/mm2). Thickness of each lamina=0.129mm and the total thickness of the laminate is h=2.58mm as shown in the Fig [8].

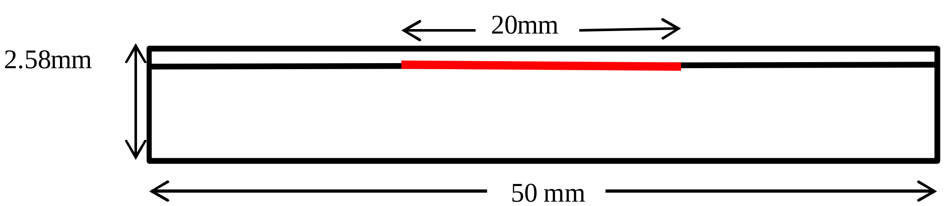


Fig 3: Illustration of the specimen

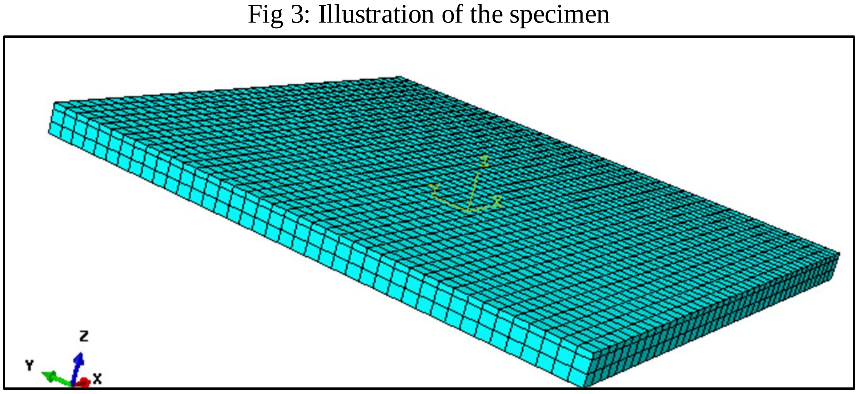


Fig 4: Meshed plate

The above Fig shows the meshed plate of the specimen whose boundary conditions are u1=u2=u30 on the left extreme side and u2=u3=0 on the right side with a compressive load of u1=0.30819mm is applied for the first step as that was the buckling load obtained in terms of displacement. And for the second step, 1.5mm is applied. The top and bottom sides are applied with u3=0.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 9 Issue VI Jun 2021- Available at www.ijraset.com

IV. RESULTS AND DISCUSSION

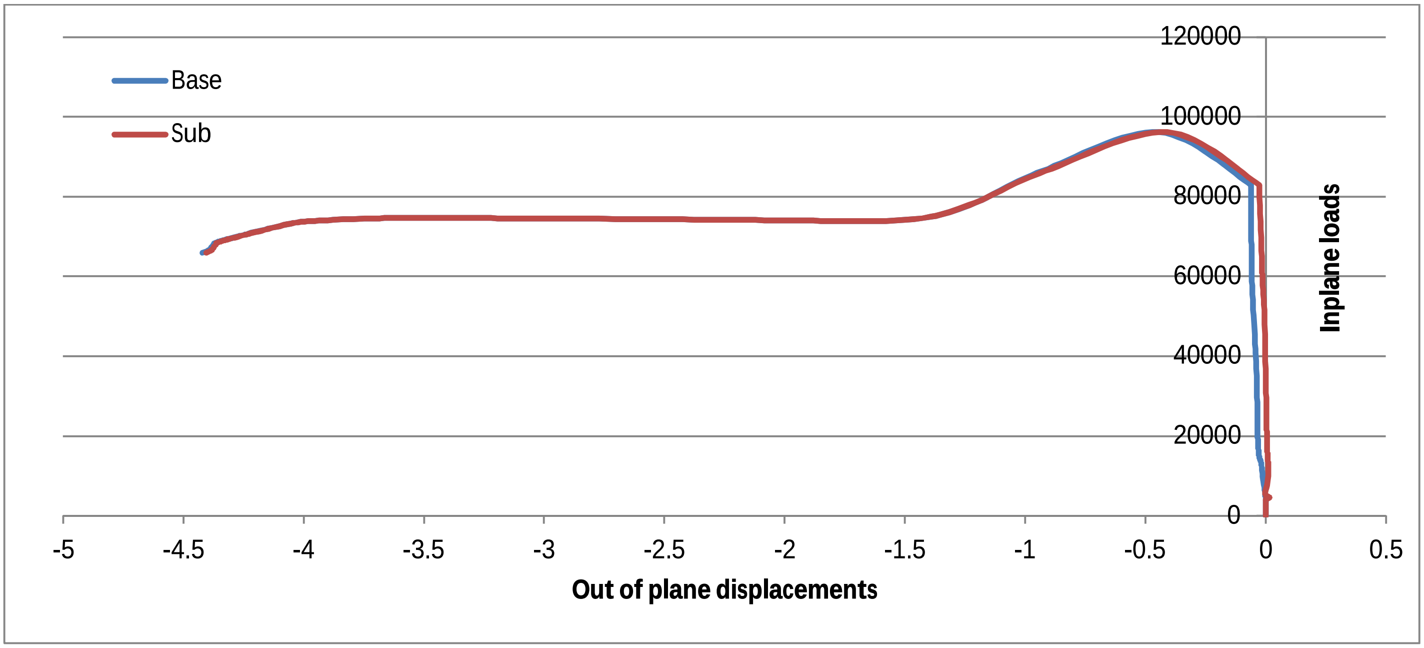


Fig 5: Inplane loads vs Out of plane displacements

Inplane loads at the left support versus out of plane displacements at the centre of the base and sublaminate is plotted as shown in Fig 5. From the plot it can be clearly observed that buckling occurs at 165N. In this case Local buckling cannot be observed. The initial post-buckling response is ruled by the buckling of the thinner sub-laminate alone which is known as thin-film buckling. Postbuckling behaviour can be either stable or unstable. In this analysis, stable post-buckling occurs at the delamination growth initiation later the shape changes to an opening mode shape occurs at 82KN. And afterwards slowly the laminate makes a transition to global mode at 73KN and then collapses.

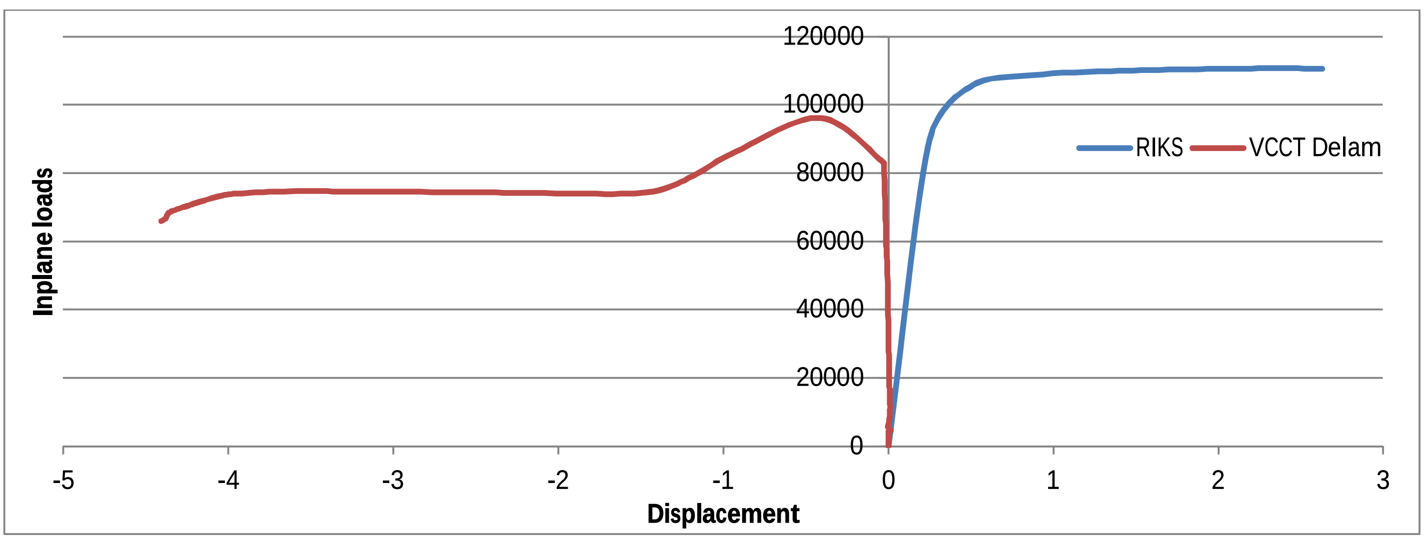


Fig 6: Inplane loads vs Out of plane displacement

Fig 6 shows plot of inplane loads versus out of plane displacement of the specimen considered in this paper by RIKS method and Delamination using VCCT. It is clear that the overall load carrying capability has reduced considerably which is about 110KN before collapse.

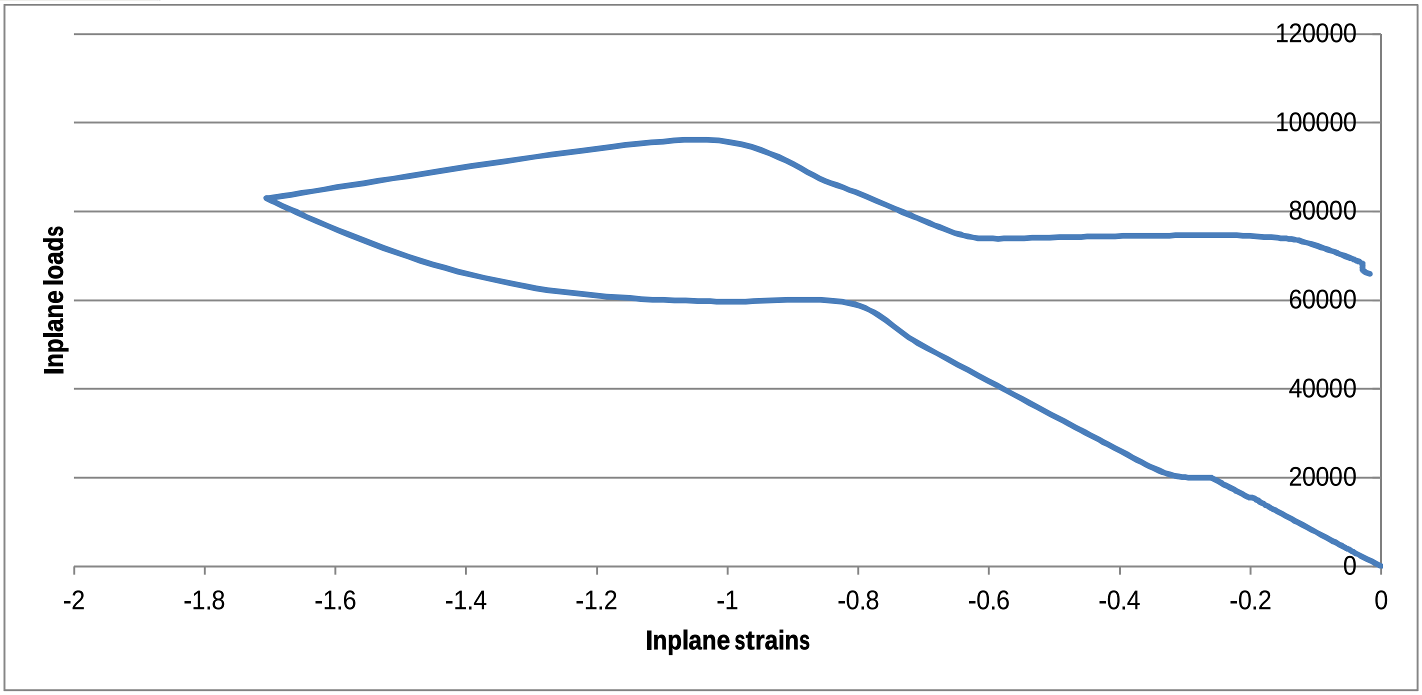


Fig 7: Inplane loads vs Inplane strains

The above Fig 6 shows the behavior of the specimen in which inplane loads versus inplane strains is plotted in which opening mode shape occurs at 82KN and with the propagation of delamination the surfaces of base and sub laminates contact each other at 73KN.

V. CONCLUSION

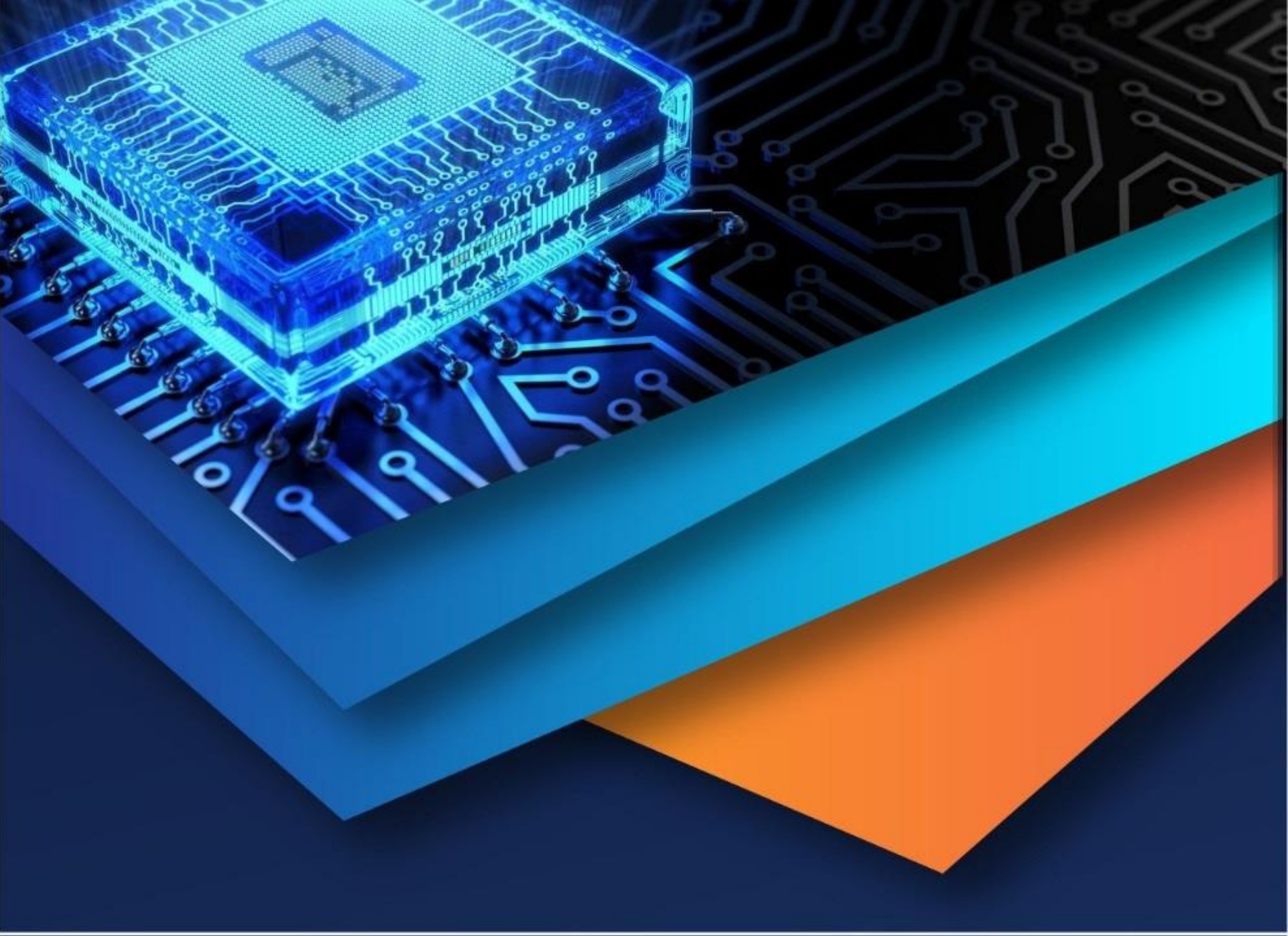
In this paper a specimen considered from [8] is analyzed computationally using VCCT in ABAQUS CAE. From the analysis, buckling, post buckling using both RIKS and VCCT has been observed and compared for reduction in load carrying capacity followed by damage evolution and the transitions made by base and sub laminates so that local buckling is not observed there was , opening mode delamination followed by global mode buckling were observed.

VI. ACKNOWLEDGEMENT

I thank my family and almighty for everything.

REFERENCES

[1] Whitcomb JD, Shivakumar KN. Strain-energy release rate analysis of plates with postbuckled delaminations. J Compos Mater 1989;23:714–34.
[2] Chai H, Babcock CA, Knauss WG (1981),"One dimensional modelling of failure in laminated plates by delamination buckling", Int J Solids Struct.17(11):1069–83.
[3] Chai H, Babcock C (1985). Two-dimensional modelling of compressive failure in delaminated laminates. J Compos Mater. 19:67–98.
[4] Nilsson KF, Asp LE, Alpman JE, Nystedt L. Delamination buckling and growth for delaminations at different depths in a slender composite panel. Int J Solids Struct 2001;38:3039–71.
[5] Riccio A, Perugini P, Scaramuzzino F. Modelling compressive behavior of delaminated composite panels. J Comput Struct 2000;78:73–81.
[6] Lachaud F, Lorrein B, Michel L, Barriel R. Experimental and numerical study of delamination caused by local buckling of thermoplastic and thermoset composites. J Compos Sci Technol 1998;58:727–33.
[7] R. Krueger (2004), "Virtual crack closure technique: history, approach, and applications," Applied Mechanics Reviews, vol. 57, no. 2, pp. 109–143.
[8] Bijan Mohammadi, Farhad Shahabi, S.A.M. Ghannadpou, Post-buckling delamination propagation analysis using interface element with de-cohesive constitutive law, Procedia Engineering, Volume 10, 2011, Pages 1797-1802, ISSN 1877-7058, https://doi.org/10.1016/j.proeng.2011.04.299.
[9] Tashkinov, M. A., Modelling of fracture processes in laminate composite plates with embedded delamination Frattura ed Integrità Strutturale, 39 (2017) 248-262.



10.22214/IJRASET

INDEX COPERNICUS

45.98

IMPACT FACTOR: 7.129

TOGETHER WE REACH THE GOAL

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY