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

DOI: https://doi.org/10.22214/ijraset.2021.36122

FEA of Circular Embedded Delamination with Variations in Temperature in 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 FRP laminates are widely implemented in aviation industry due to its advantages and applications other materials in terms of strength to weight ratio, design 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 circular shape delamination geometry of 60mm buckling driven delamination growth with variations in temperature for -20C, room temperature, 523C, 773C and 1273C. The computational prediction of delamination growth initiation is obtained by solving a CFRP specimen for geometric non linearity using SC8R continuum shell elements of Abaqus CAE and by plotting the required energy release rate versus inplane strains and inplane loads versus compressive strains.

Keywords: Circular embedded delamination, VCCT, uniaxial compression, B-K criterion, energy release rate, temperature effects.

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 with variations in temperature 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 one step 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 with no changes in stress considerably as shown in Fig 1and 2 [7]. This procedure is based on Irwin's crack closure method which is a two-step process. The work ΔE required to close the crack along one element side can be calculated as

$$\Delta \mathbf{E} = \frac{1}{2}[\mathbf{X1l}.\Delta \mathbf{u}_{2l} + \mathbf{Z1l}.\Delta \mathbf{w}_{2l}]$$

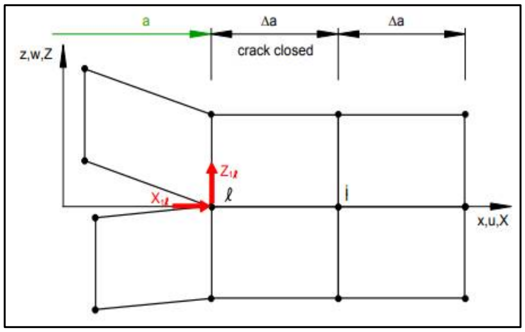


Fig 1: First step crack closed

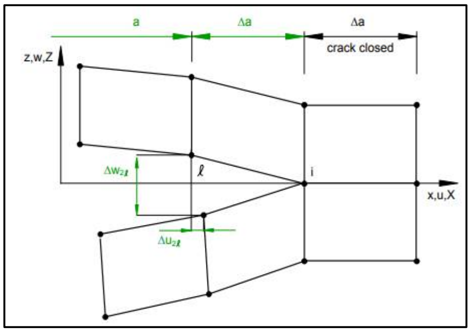


Fig 2: Second step crack extended

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 $[0/90/0//0/(90/0)_6]$ is considered which is made of the CFRP as in [8]. 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 CFRP are E_{11}=139400 (N/mm2), $E_{22}=E_{33}$=10160 (N/mm2), $G_{12}=G_{13}$=4600 (N/mm2), G_{23}=3500 (N/mm2), $\nu_{12}=\nu_{13}=0.3$, $\nu_{23}=0.43$, $G_{IC}=0.3$, $G_{IIC}=0.48$ (J/m^2). Thickness of each lamina=0.18mm and the total thickness of the laminate is h=2.88mm as shown in the Fig [8]. The imperfection factor used is 1.27% or 0.05.

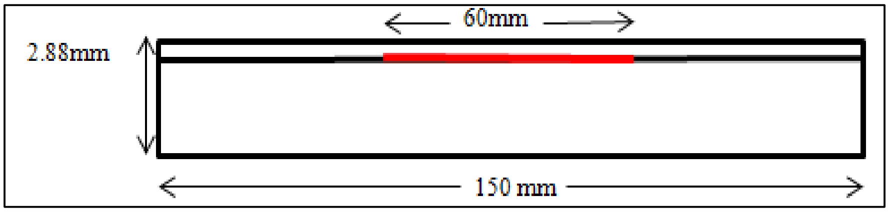


Figure 3: Illustration of the specimen

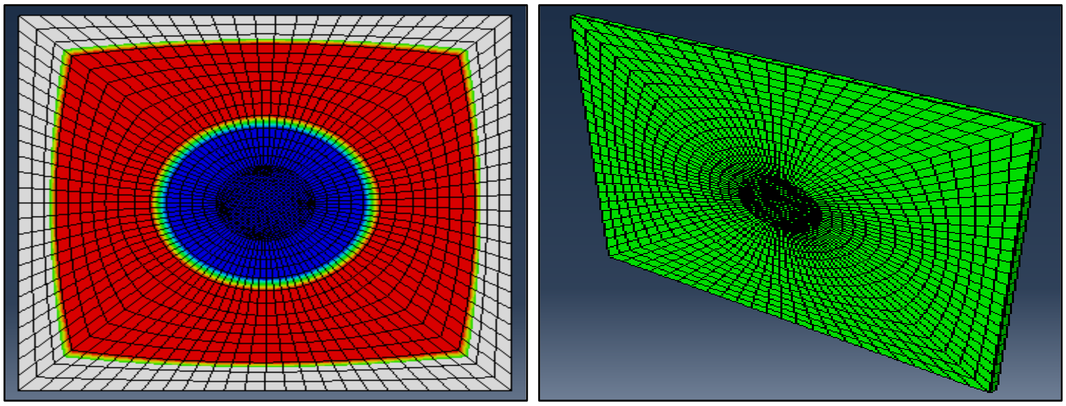


Fig 4: Meshed plate

The above Fig shows the meshed plate of the specimen whose boundary conditions are u1=u2=u3=0 on the top and bottom sides with a finite displacement value of 0.5mm and 1.5mm applied as displacement loads at the bottom in terms of a two-step analysis and u3=0 on the right and left sides.

IV. RESULTS AND DISCUSSION

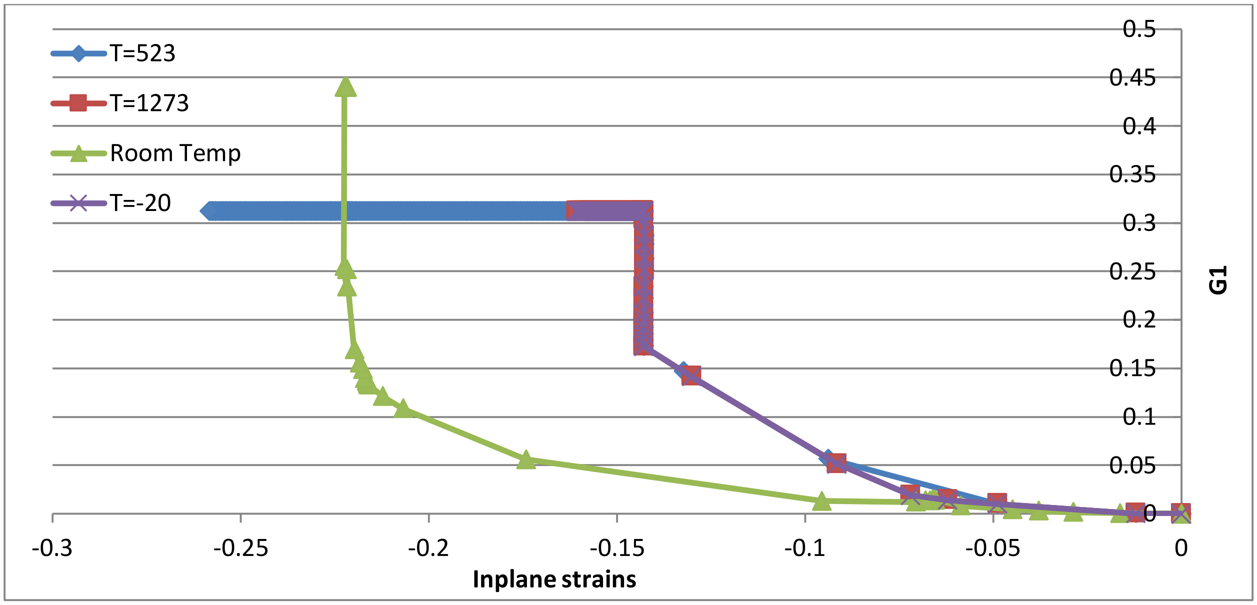


Fig 5: Mode I SERR vs Inplane compressive strains

In the figure mode 1strain energy release rate (SERR) versus inplane compressive strains is plotted for the CFRP laminate considered from [8] by varying the temperature for T=-20, Room temperature, 523, 773, 1273 as shown above (figure 5). From the plot it can be clearly observed that when the specimen is under room temperature, mode 1 strain energy release rate follows a linear variation and smooth variations followed by sudden increase in the response and reached 0.45 J/m^2. For all the other subcases when T=523, 773, 1273 and -20, the response is linear and suddenly abruptly rises vertically upto 0.3. So the mode 1 strain energy release rate required to cause delamination growth initiation for a specimen under 523, 1273, 773, 1273 is 33% lesser to that of the energy release rate required by the specimen in room temperature.

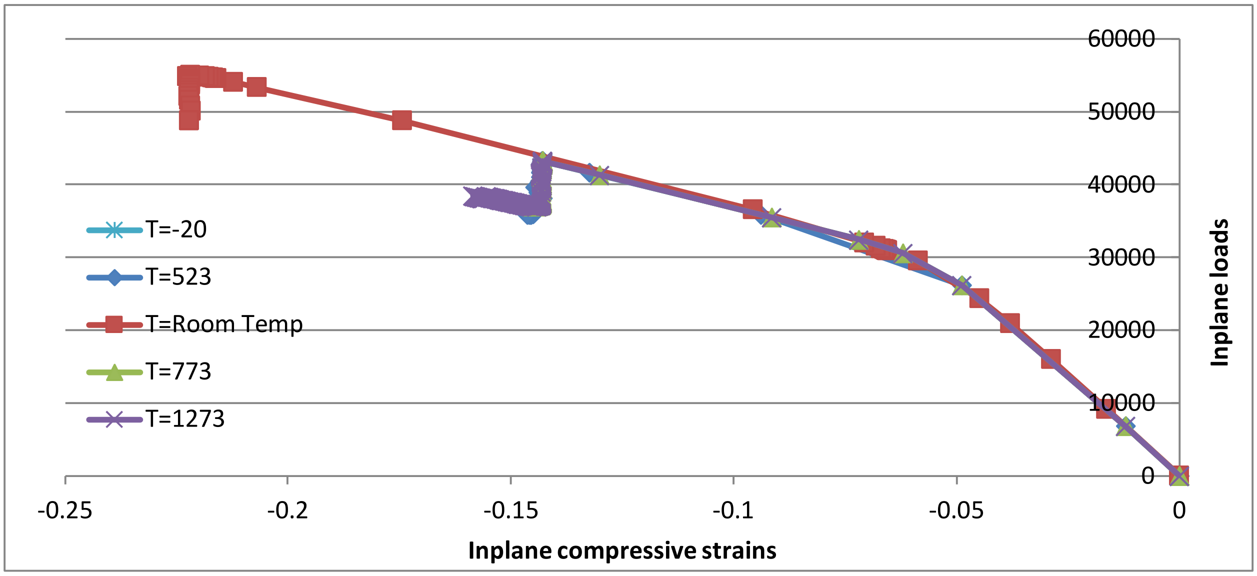


Fig 6: Inplane loads vs Inplane strains

The above figure 6 shows the behavior of the specimen in which inplane loads versus inplane strains is plotted. From the figure it is evident that the load required by the laminate to initiate delamination under room temperature is about 56800N. Whereas for all other cases when the temperature is -20, 523, 773, 1273, the load required by the specimen is 44000N. Hence it is clear that a variation in temperature reduces the required load to initiate the delamination.

V. CONCLUSION

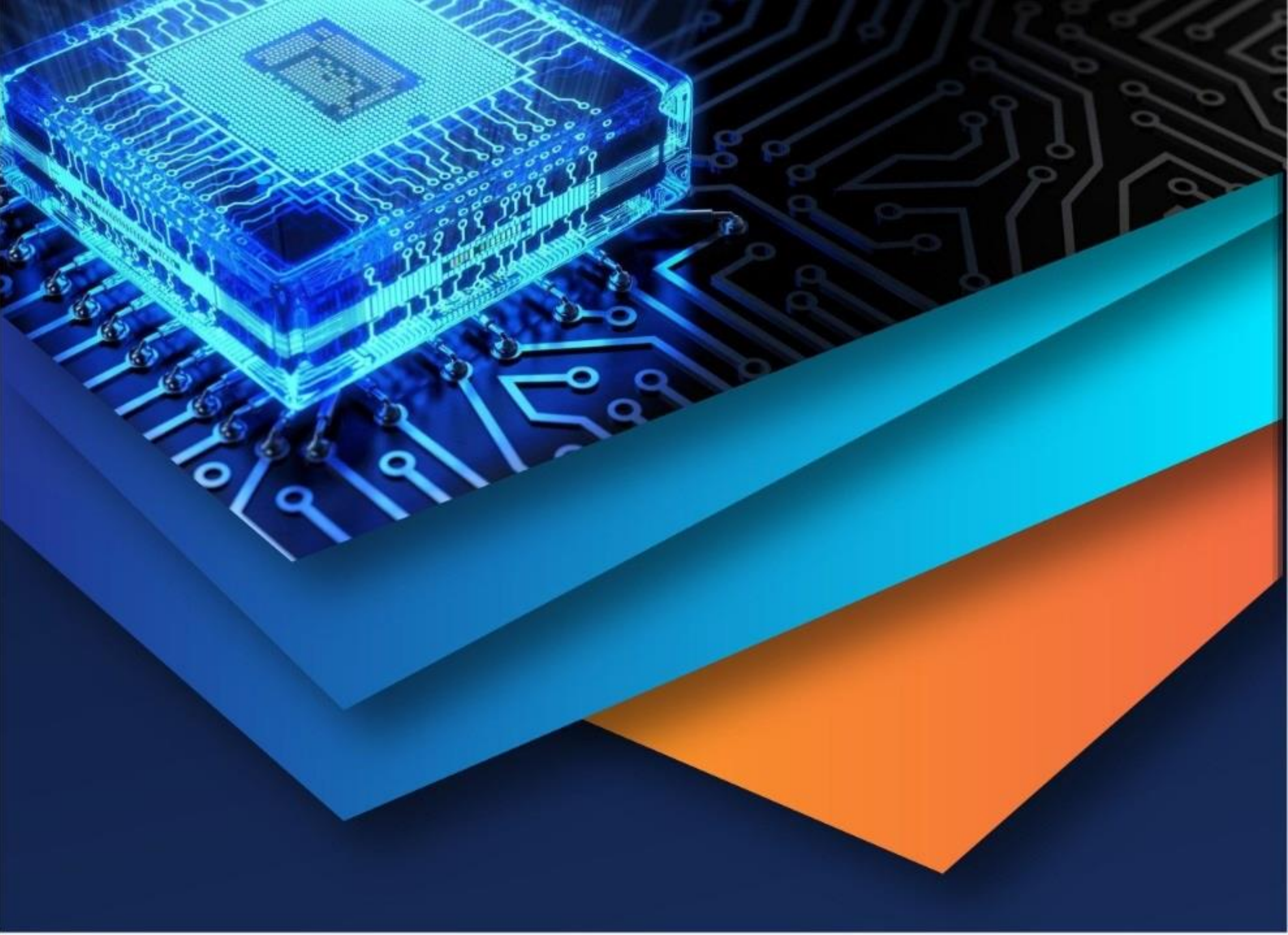
In this paper a specimen considered from [8] is analyzed computationally using VCCT in ABAQUS CAE. From the analysis, it is observed that the energy release rate and the load required to initiate delamination is 50% more and 23% more for a composite laminate in room temperature in comparison to that of laminate under temperatures, T=-20, 523, 773, 1273C.

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] Raju J., Duragkar M.S., Jagannathan N., Manjunatha C.M., 2013. Finite Element Analysis and Prediction of Onset of Mode I Delamination Growth under a Tensile Spectrum Load Sequence, ISAMPE National Conference on Composites INCCOM-12.
[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

45.98

IMPACT FACTOR:
7.129

IMPACT FACTOR:
7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY