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Research Paper

Buckling Behavior of Laminated Composite plate under Thermal Load

K Mahadevaswamy [1], Khamar Taj [2], Vinaya [3]
[1] *Senior Scale lecturer, Department of Mechanical engineering (HPT), S J (Govt.) Polytechnic Bangalore, Karnataka, India.*
[2] *Senior Scale lecturer, Department of Automobile Engineering, S J (Govt.) Polytechnic Bangalore, Karnataka, India.*
[3] *Senior Scale lecturer, Department of Chemical Engineering, S J (Govt.) Polytechnic Bangalore, Karnataka, India.*

ABSTRACT: *The maximum amount of stress that can be tolerated by a material has significantly increased as a consequence of developments in material science. This is especially true in the case of composite materials that have lately been developed that are both lightweight and high-strength. Composites that make use of fibers as reinforcement generally consist of a matrix and high-modulus fibers that are either injected into the matrix or linked to the matrix at different places. There is no change in the physical and chemical characteristics of the fibers and matrix inside this structure; nonetheless, the combination of these two components results in a composite of characteristics that neither of the components could attain on their own. In this work, the buckling properties of laminates are investigated in relation to the influence of uniformly distributed temperature loads that are produced by the construction of finite element formulation for the material. As a consequence of these discontinuities in the panels, the in-plane thermal stress distribution inside the panel may be difficult. This is because the stress field is not only uniform, but the presence of stresses may also vary in various places, which may lead to a loss of stability at an incredibly low level of stress. Therefore, it is very vital to have a comprehensive understanding of various formed panels that have cut-outs in order to avoid early failure and to make use of their full power. This is something that may be significantly investigated in the field of thin-walled constructions.*
Keywords: *Buckling, Laminated Composite plate, Epoxy Resin, Composite Material. Thermal Load.*

I. INTRODUCTION

The maximum amount of stress that can be tolerated by a material has significantly increased as a consequence of developments in material science. This is especially true in the case of composite materials that have lately been developed that are both lightweight and high-strength. In the majority of instances, cut-outs or holes are supplied for laminated panels in order to fulfill certain functional standards. These specifications include the ability to easily access the panels for inspection, the ability to pass through hydraulic lines, fuel lines, and electrical lines, and often for the purpose of decreasing the overall weight of the structure. As a consequence of these discontinuities in the panels, the in-plane thermal stress distribution inside the panel may be difficult. This is because the stress field is not only uniform, but the presence of stresses may also vary in various places, which may lead to a loss of stability at an incredibly low level of stress. Therefore, it is very vital to have a comprehensive understanding of various formed panels that have cut-outs in order to avoid early failure and to make use of their full power. This is something that may be significantly investigated in the field of thin-walled constructions. The fiber-reinforced composite constructions are susceptible to the impacts of increased temperature loads throughout their operational life, which results in a significant reduction in strength as well as other detrimental consequences. Through the use of the finite element approach, Biswal, Sahu, and Asha (2016) conducted an investigation into the impact of hygrothermal stress on the buckling behavior of laminated composite shells. For the purpose of modeling the shell, a quadratic iso-parametric eight-noded shell element with first order shear deformation was used. Moreover, an experiment was carried out in order to back up these findings. In order to investigate the parametric instability of laminated plates that were exposed to periodic dynamic loads in a hygro-thermal environment, Rath and Sahu (2013) used a finite element modeling technique. Panda et al. (2013) conducted theoretical and analytical research based on the finite element factors in order to investigate the impact of hygrothermal conditions on the free vibration of delaminated woven composite fiber plates. A study was conducted by Sahu and Parhi (2013) to investigate the vibrational activities of woven fiber glass and epoxy delaminated composite plates that were exposed to extreme temperatures and humidity. For the purpose of modeling the plate, a quadratic iso-parametric element with eight nodes and five degrees of freedom per node was used. Additionally, first order shear deformation theory (FSDT) was utilized. An investigation of the thermal buckling behavior of shear deformable functionally graded single / doubly curved shell panels with TD and TID features was carried out by Vishesh R. Kar and Subrata K. Panda (2016). The thermal buckling behavior of the FG plate was explored by Na and Kim (2004) by the use of the finite element technique (FEM) using a three-dimensional solid element with eight nodes to investigate. In this study, Abdelhak et al. (2015) investigated the thermal buckling behavior of FGM plates by using the four variable theory in the nth order. A sinusoidal hypothesis was used by Ashraf M. Zenkour (2012) in order to investigate the hygrothermal effects that were seen on the bending of angle-ply composite plates. Sai Ram and Sinha (1991) have used the finite element approach in order to illustrate the hygrothermal effects that have been seen on the stretching behavior of laminated composite laminated plates. Shen et al. (2001) conducted research to investigate the impact of a hygrothermal environment on the postbuckling behaviors of laminated plates that were based on Reddy's HOPT.

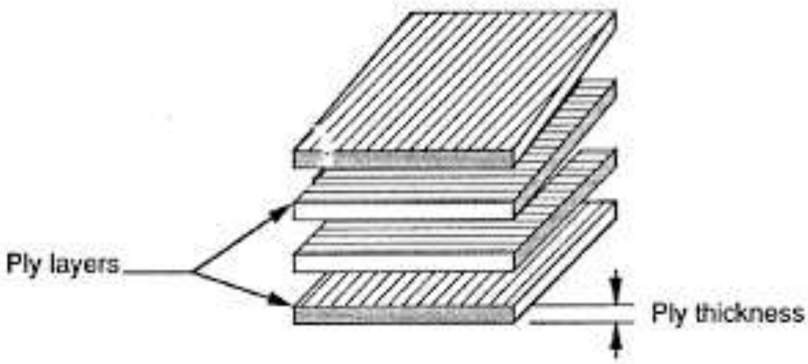

Figure 1: Laminated Composite Plate

II. STRUCTURE OF EPOXY

Epoxy matrices are constructed from organic liquid resins that have a low molecular weight and include a number of epoxide groups. These resins are the building blocks of an epoxy matrix. Epoxide groups are made up of three carbon atoms and one oxygen atom in each and every composition. Because it has two epoxide groups—one on each end of the molecular bond—diglycidyl ether of bisphenol A, also known as DGE BA, is a common starting material. Diluents, which cause the beginning liquid to become less viscous, and flexibilizers, which cause the cured epoxy matrix to become more robust, are two examples of additional chemicals that may be added to the initial liquid.

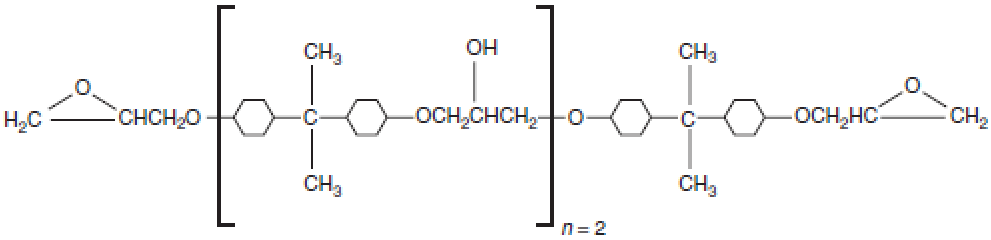

Figure 2: Principal ingredients in the preparation of an epoxy matrix

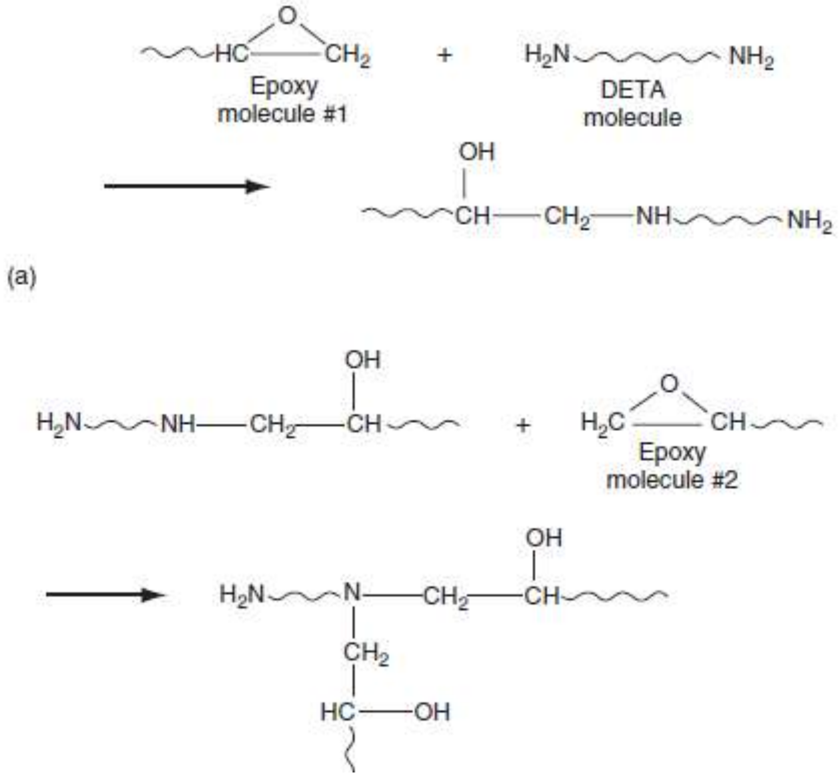

Figure 3: Schematic representation of a cross-linked epoxy resin

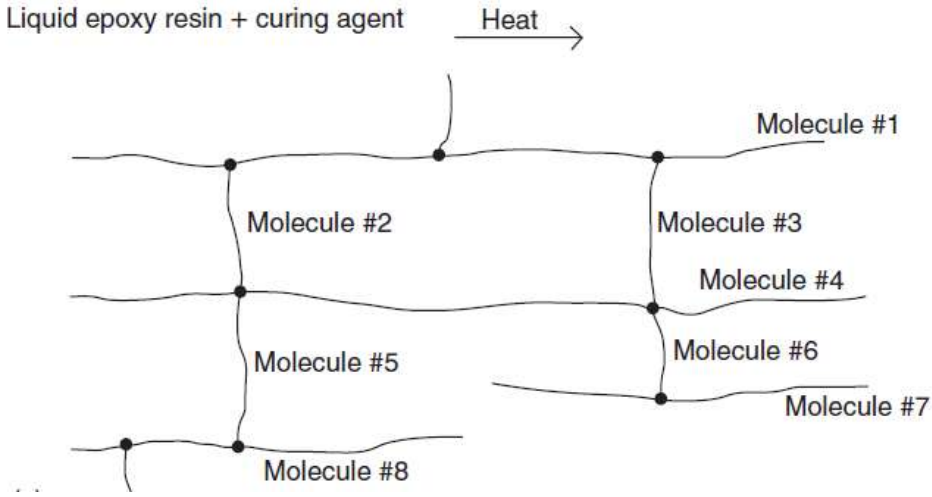

Figure 4: Three-dimensional network structure of solid epoxy

III. RESULTS AND DISCUSSION

When it comes to tackling eigenvalue issues, there are a few different techniques. In order to acquire the Eigenvalues, the subspace iteration approach is used in this study. This technique is employed in order to find numerical solutions to the issue. Multiple thicknesses will be included in the angle-ply and cross-ply laminated composite plates that will be used in this application. These plates will be symmetrically bonded.
The thermo-elastic properties of the material that are considered for E-glass / epoxy are shown in Table 1.

Table 1 Material properties used for numerical solutions at different temperature

Elastic moduli (GPa)	Temperature T (K)					
	300	325	350	375	400	425
E_1	130	130	130	130	130	130
E_2	9·5	8·5	8·0	7·5	7·0	6·75
G_{12}	6·0	6·0	5·5	5·0	4·75	4·5

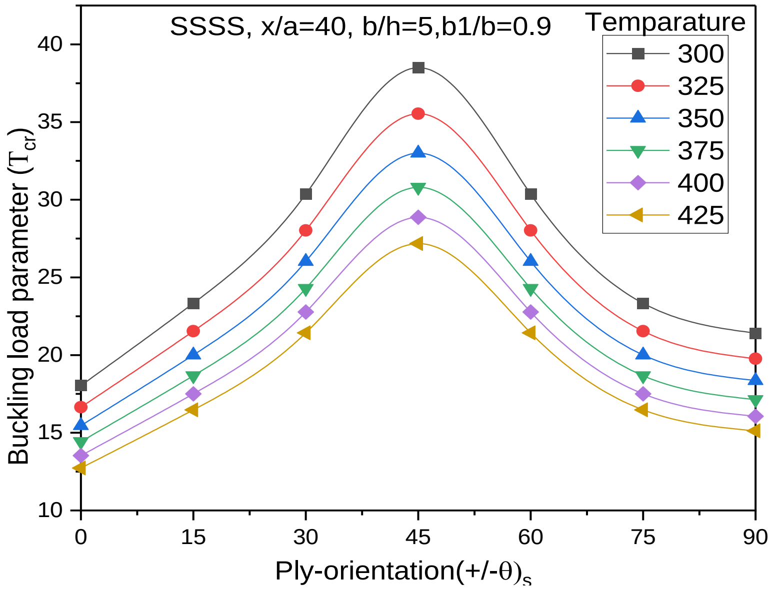

Figure 5: Thermal buckling behavior under thick laminate (b) thin laminate.

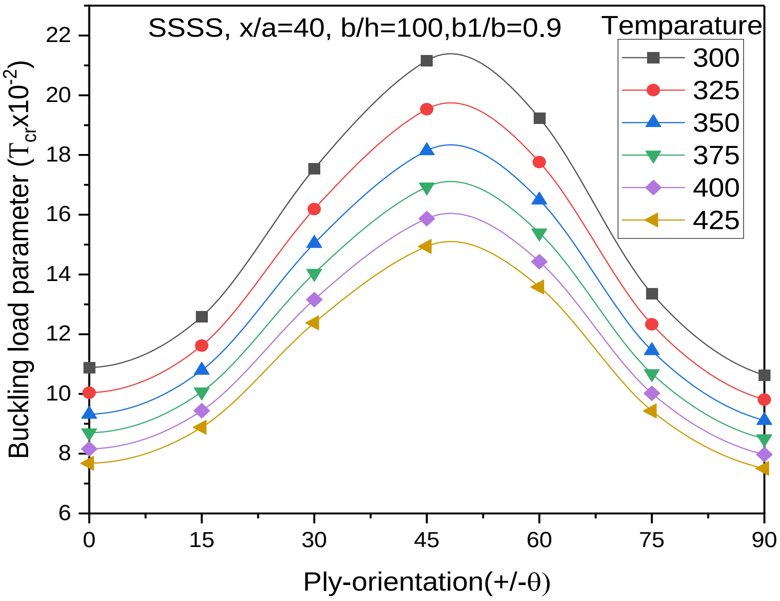

Figure 6:Thermal buckling behavior under thin laminate.

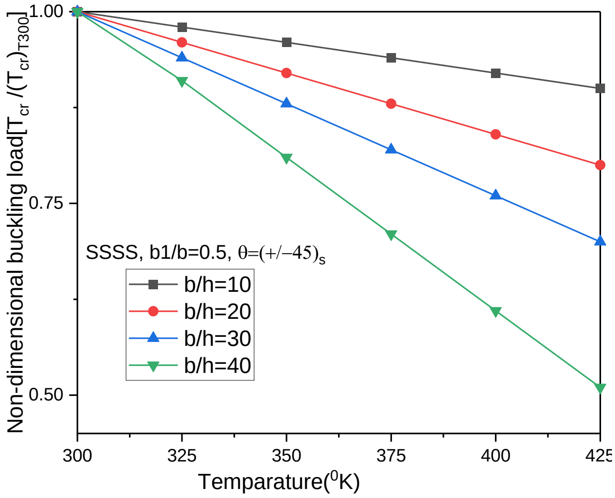

Figure 7: Impact of boundary conditions under thermal buckling load with SSSS

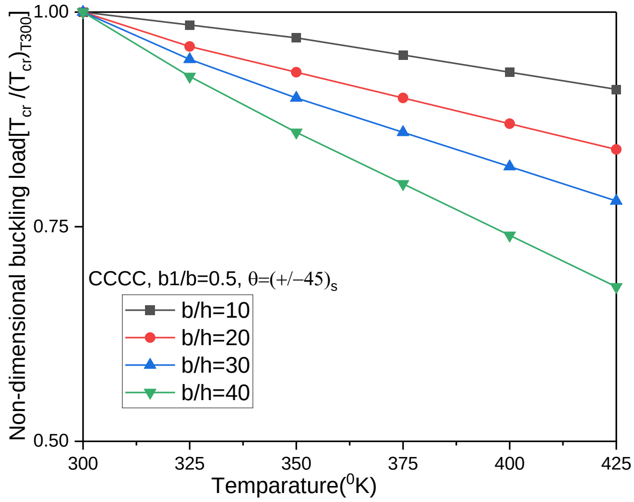

Figure 8: Impact of boundary conditions under thermal buckling load with CCCC

An investigation into the influence of cutout size on the non-dimensional stability resistance of simply supported (SSSS) and clamped (CCCC) rectangular plates was carried out by taking into account an angle-ply layup scheme. The numerical findings of this investigation are shown in Figures above. This inquiry takes into consideration a rectangular plate that is exposed to a uniform thermal load. Based on the findings of the research, it is evident that the CCCC boundary condition exhibits a stronger buckling resistance in comparison to the SSSS boundary condition throughout a range of temperatures and thicknesses. Only under thin plate circumstances does the influence of CCCC and SSSS boundary conditions play a substantial part in the non-dimensional buckling resistance of the rectangular-shaped plate. This is something that should be taken into consideration.

IV. CONCLUSIONS

Taking into consideration an angle-ply layup scheme, an experiment was carried out to determine the impact that the size of the cutout has on the non-dimensional stability resistance of simply supported (SSSS) and clamped (CCCC) rectangular plates. As may be seen in the figures that are located above, this inquiry yielded numerical data. Through the course of this investigation, a rectangular plate that is subjected to a consistent thermal stress is taken into account. Throughout a wide range of temperatures and thicknesses, it is clear that the CCCC boundary condition has a higher buckling resistance in comparison to the SSSS boundary condition. This is the conclusion that can be drawn from the outcomes of the study. The effect of CCCC and SSSS boundary conditions only plays a significant role in the non-dimensional buckling resistance of the rectangular-shaped plate when the circumstances are such that the plate is thin. Regarding this particular matter, it is important to take it into mind.

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