International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 3 Issue 10, October- 2014

Thermal Buckling Analysis of Laminated Composite Plate

Kandi. Ashok
P. G. student, Aerospace Engineering
MLR Institute of Technology
Hyderabad, India

Dr. S. Srinivas Prasad
Professor & Head,
Department of Aeronautical Engineering
MLR Institute of Technology
Hyderabad, India

Srikanth Sikhakolli
Post Graduate,
Aerospace Engineering
MLR Institute of Technology
Hyderabad, India

***Abstract*— Aerospace in one such field where the structural components undergo through various combinations of loads always. So coupled field analysis in this field of application has become quite compulsory. One such kind of analysis is thermal buckling analysis. Thermal buckling analysis of laminated smart composite plates subjected to uniform temperature distribution has been presented in this paper. Shape memory alloy (SMA) fibers whose material properties depend on temperature is used as smart material. Finite Element Analysis (FEA) tool ANSYS 14.5 was used to observe the effects of thickness ratio, fiber orientation on the critical buckling temperature.**

Keywords — Shape Memory Alloys, Thermal buckling, FEA, thickness ratio, fiber orientation

I. INTRODUCTION

A structure or a material is defined "smart" if they are able to perceive external stimulus and to act on that a real time active control. Recently the development of new Aeronautical Structures and the implementation of innovative materials have been mandatory for succeeding in critical tasks in terms of weight, fuel consumption, aerodynamic efficiency, cost reduction and so on. [1]

The SMAs are a class of materials that exhibit a martensitic transformation when cooled from the higher-temperature austenite state. The interaction of temperature and applied stress in driving the martensitic and reverse transformations can be used to exploit the phenomena such as the shape memory effect SME and pseudo-elasticity. The two main types of shape-memory alloys are the copper-aluminum-nickel, and nickel-titanium and (NiTi) alloys but SMAs can also be created by alloying zinc, copper, gold and iron. NiTi alloys are generally more expensive and change from austenite to martensite upon cooling [2].

In the last years aeronautic civil sector has signed a considerable economic growth due to an increase of 6% every year [6]. So that many companies like Boeing and Airbus have the intent to develop new aircraft concept and design for the development of cargo and passenger transport for the next 25 years [3].

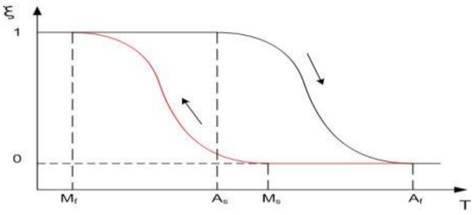

Figure 1. Transition of nitinol (SMA) from the marten site phase to the austenite phase

Boeing, General Electric Aircraft Engines, Goodrich Corporation, NASA, and All Nippon Airways developed the Variable Geometry Chevron using shape-memory alloy that reduces aircraft's engine noise.

II. CRITICAL BUCKLING TEMPERATURE CALCULATIONS

The buckling behavior due to the uniform temperature is calculated non-dimensionally using the formula

$$T_{cr} = \lambda.\Delta t.\alpha.10^3$$

Laminate	Critical buckling temperature
Without SMA	1.12
With SMA	1.96

Table 1. Hand calculation values of critical buckling temperature

Where,

ΔT – Change in temperature

α – Coefficient of thermal expansion

λ – Critical buckling temperature parameter

III. METHODOLOGY

A 2-D SMA fiber- reinforced composite plates using layer-wise model is to be developed. The composite plates are subjected to uniform temperature; an incremental load technique is used for the analysis. The buckling temperature results of the laminated plates with SMA and without SMA fibers are compared for the cases kept in table 2.

Varying thickness ratio (a/h)	Fiber orientation
20	-10/0/10
40	-45/0/45
60	-90/0/90
80	
100	

Table 2. various cases considered for the analysis

Elastic Modulus	E_{11} = 1.55 GPa	E_{22} = 8.07 GPa	E_{33} = 8.07 GPa
Poisson's ratio	μ_{12} = 0.22	μ_{23} = 0.348	μ_{31} = 0.22
Modulus of Rigidity	G_{12} = 4.55 GPa	G_{23} = 3.25 GPa	G_{31} = 4.555 GPa
Coe. of thermal expansion	α_x=-1017e-6	α_y=30e-6	α_z=30e-6
Density	1.59e-3		
Thermal conductivity	8.3075		
Specific heat	1.3		

Table 3. Properties of graphite epoxy

Elastic Modulus	83 GPa
Poisson's ratio	0.33
Coe. Of thermal expansion	11e-6
Density	6.45e3
Thermal conductivity	18
Specific heat	200

Table 4.. Properties of Nitinol

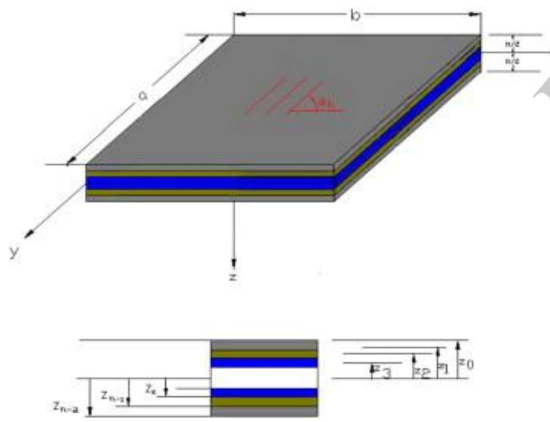

Figure 2. layer-wise model

Length along X-axis is denoted as "a"
Length along y-axis is denoted as "b"
Thickness along z-axis as "h"

IV. FINITE ELEMENT MODELLING AND ANALYSIS

A. Modeling

a = 0.5 m
b = 0.8 m

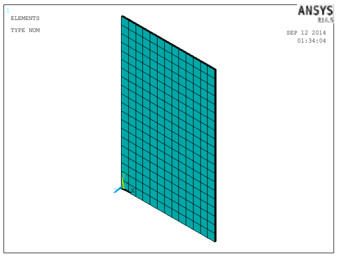

Figure 3. Meshed layer-wise model

B. Analysis

The thermal and static analysis is done on the composite plate by applying material properties. The thermal analysis is done by applying temperature of 274 k on the surface of the plate.

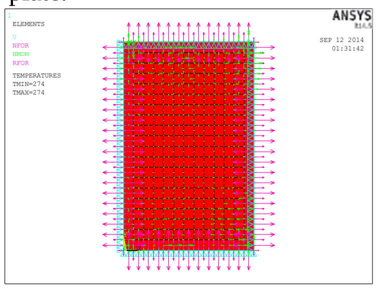

Figure-4: Applied Boundary Conditions

V. RESULTS AND DISCUSSION

The below figures shows the results of the nodal solution for the deformed + Un-deformed shape, displacement vector sum and von-mises stress.

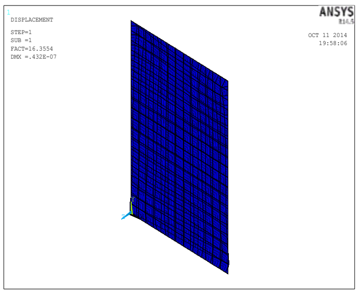

Figure 5. Deformed + Undeformed shape for a/h = 60 (without SMA)

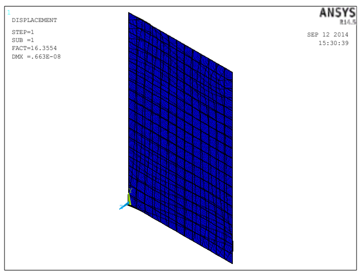

Figure 6. Deformed + Undeformed shape for a/h = 60 (with SMA)

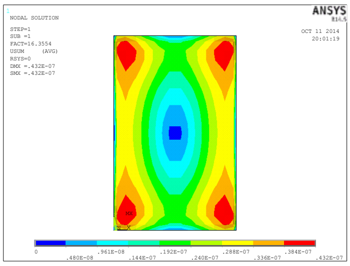

Figure 7. Displacement vector shape for a/h= 60(with out SMA)

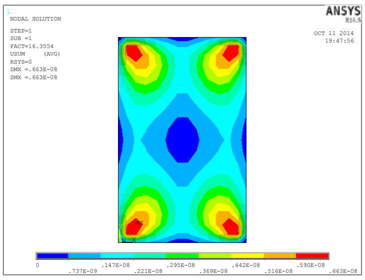

Figure 8. Displacement vector shape for a/h= 60(with SMA)

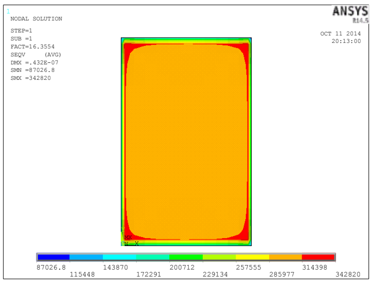

Figure 9. von- misses stress for a/h = 60(without SMA)

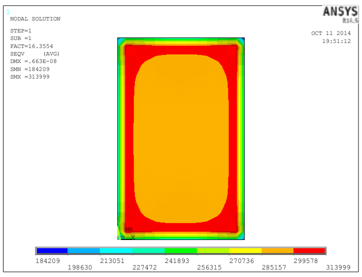

Figure 10. von- misses stress for a/h = 60(with SMA)

Thickness ratio a/h	Orientation [-10/0/10]	Orientation [-45/0/45]	Orientation [-90/0/90]
20	0.506e-07	0.200e0-7	0.105e-17
40	0.289e-07	0.108e-07	0.105e-17
60	0.182e-07	0.0752e-07	0.105e-17
80	0.132e-07	0.0568e-07	0.105e-17
100	0.102e-07	0.0450e-07	0.105e-17

Table 5. Comparison of deformation results for different thickness ratio's and orientation for with out SMA

Thickness ratio a/h	Orientation [-10/0/10]	Orientation [-45/0/45]	Orientation [-90/0/90]
20	0.912e-08	0.198e-08	0.708e-18
40	0.486e-08	0.101e-08	0.708e-18
60	0.318e-08	0.663e-08	0.708e-18
80	0.245e-08	0.503e-08	0.708e-18
100	0.195e-08	0.403e-08	0.707e-18

Table 6. Comparison of deformation results for different thickness ratio's and orientation for with SMA

From the results we can understand that the 90/0/90 orientation is not at all suitable in concern of stiffness criterion in both the cases of using SMA and without using SMA. While coming to other cases, the -45/0/45 lay-up case is showing considerable stiffness when compared to -10/0-10 lay-up case. And when compared to with and without SMA usage, the plate with SMA has shown considerable less deformation.

As per the strength criterion, the stresses result that we got will again depend on the material properties that we are using. But from the results we got we can say that the material is safe in both the conditions.

VI. CONCLUSION

The displacement at the each point along the different thickness and lamina orientations are found out and the results are compared with the composite laminates alone and the laminates with SMA fibers. With the incorporation of the SMA fibers into the composite laminate, the thermal buckling temperature has been enhanced and hence SMA composites can withstand higher temperatures and can be used in the environments where the structures are exposed to high temperatures.

VII. REFERENCES

1. Pecora R., Analisi della lamina ortotropa e teoria classica dei laminati, Italy (2006) 2-10
2. Davidson, B.D., Hu, H., and Schapery, R.A., An Analytical Crack Tip Element for Layered Elastic Structures, Journal of Applied Mechanics, (1995) 294-305.
3. M. Granito, A cooling system for S.M.A. (shape memory alloy) based on the use of peltier cells, Philosophy thesis, University of Naples "Federico II" – ITALY.
4. A.L. Martins and F.M. Catalano, "Viscous Drag Optimization for a Transport Aircraft Mission Adaptive Wing", 21st ICAS Congress, Melbourne, Australia Paper A98-31499 (1998).