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Research Article

Thermal Buckling of Laminate Composite Spheroidal Spherical Shell

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Abstract

Thermal buckling analysis of multi-layered composite spheroidal spherical shells with clamped boundary condition under uniform distribution thermal load is investigated using the finite element method to produce the theoretical modeling. The results obtained are compared with the know data in the literature for composite shells. The effect of important parameter spherical angle, fiber orientation, number of layers of composite shell and radius to thickness ratio are taken in to consideration on the structure stability.

Keywords: *thermal buckling, composite spheroidal spherical shell, finite element method*

Introduction

Spherical shells constitute an important portion in many engineering structures. They can find applications in the aircraft, missile and high speed aerospace vehicles consisting of thin shell elements are subjected to aerodynamic heating which induces a temperature distribution over the surface and thermal gradient thought the thickness of the shell. These shell elements also be widely used in other industries such as shipbuilding, underground structures and building constructions.

composites are the most promising for components of current and future engineering structures (aerospace, naval, chemical and other mechanical industries) as they represent a composites between the stiffens and the lightness. Laminate composite structure are well known for their high strength –to- weight ratio, high stiffness to weigh ratio, good energy absorption, longer fatigue life, high heat resistance/low thermal expansion and often also low production cost, which adds to the versatility of composite for sensitivity application. These structures are exposed to combined loading(aerodynamic/structural) and environmental (thermal) condition during their service life, which have an adverse effect on their structural behavior.

Thermal buckling has an important role in the design of structure subjected of the thermal environment. Nowadays growing interest in shown in structural design in different branches of modern technology. The main importance in predication of mechanical behavior of such structures are in thermal working environment. For example, structures with hemispherical shape used in hypersonic airplane and rockets are under high temperature working environment.

The linear buckling analysis of laminated composite conical shells under thermal load using the finite element method was reported by **Kari[1990].** The result indicated that the buckling behavior of laminated shell under thermal load was different from the one with respect to the angle of the fiber orientation. Thermally inducer dynamic instability of laminated composite conical shells recently investigated employing perturbation approach to solve the linear three-dimensional equations of motion in terms of incremental stress perturbed from the state of natural equilibrium was studied by **Wu and Chiu[2002].** Thermal bucking and free vibration analysis of multi- layered composites conical shells based on a layer wise displacement theory and obtained the effect of the semi-vertex angle, subtended angle and radius to thickness ratio on the structural stability was performed by **Woo et. at[2007]**.

Shen [2008]. developed a boundary-layer theory for the buckling and post buckling of anisotropic laminated thin shells under mechanical loading of axial compression and external pressure and torsion and found that there exists a compressive or circumferential stress along with an associate shear stress and twisting when the anisotropic laminated cylindrical shell subjected to axial compression or lateral pressure. In contrast, there exists a shear stress along with an associate compressive stress when the anisotropic shell subjected to torsion. Accordingly, believe that there exists a compressive stress due to boundary constraints along with an associate shear stress when the shell is subjected to heating. **Hamed et al.[2009]** conducted the nonlinear long-term time-dependent behavior of spherical shallow concrete domes, in order to enhance their effective design and safe use. The paper focuses on the development of a general axisymmetric theoretical model to study the influence of creep and shrinkage on the geometric nonlinear behavior. A study of these effects, considering only the geometrically linear behavior of shallow concrete domes under service loads, where a simplified straightforward creep law used. The nonlinear long-term buckling behavior (creep buckling)

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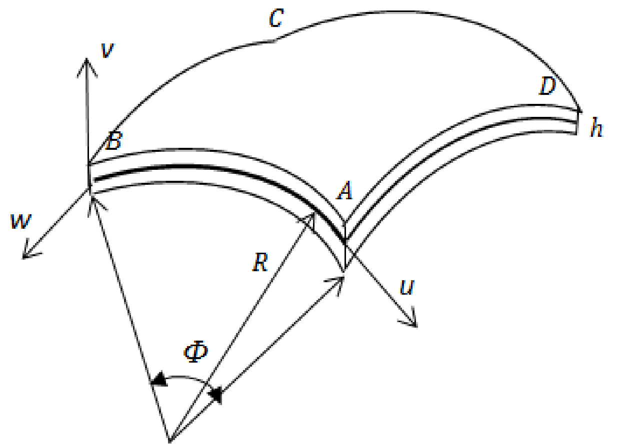

Fig(1): Geometry of Spheroidal Spherical Shell

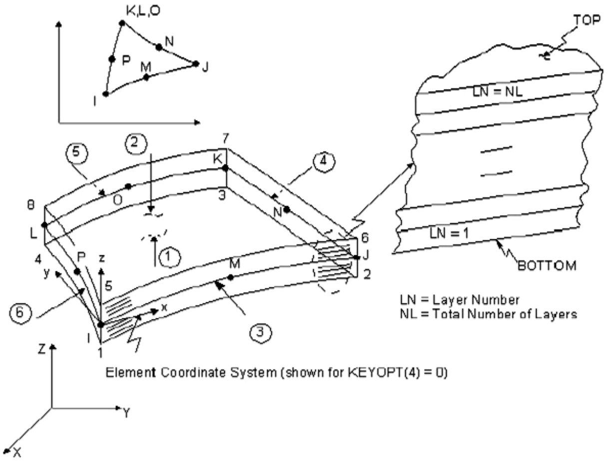

Figure (2): Shell 99 Element (ANSYS Element Reference)

of spherical shallow, thin-walled concrete shells of revolution (including domes) subjected to sustained loads The investigated show that long-term effects are critical for the design and structural safety of shallow, thin-walled concrete domes was investigated by **E. Hamed et. at.[2010].** The nonlinear thermal buckling of symmetrically laminated cylindrically orthotropic shallow spherical shell under temperature field and uniform pressure including transverse shear using the modified iteration method. The effect of transverse shear deformation and different temperature fields on critical buckling load was discussed by **Z. Yong et. at.[2008]**. The thermo mechanical buckling of simply supported the shallow spherical shells made of functionally graded material with a power law distribution for volume fraction considered, where its properties vary gradually through the shell thickness direction from pure metal on the inner surface to pure ceramic on the outer surface and it temperature dependent was presented **A. Hafezalkotob and M. R. Eslami[2010]**.

Buchanan and Rich [2002] computed the natural frequencies of spherical shells with simply supported, free and fixed boundary conditions using a Lagrange finite element in spherical coordinates. **Fan and Luah [1995]** used the spline finite element method to compute the natural frequencies of clamped hemispherical domes. **J. Lee [2009]** investigated the pseudo spectral method to the axisymmetric and asymmetric free vibration analysis of spherical caps. The displacements and the rotations were expressed by Chebyshev polynomials and Fourier series, Numerical examples provided for clamped, hinged and free boundary conditions. **J. Li, et at [2007]** presented a finite element scheme to analyze the buckling behavior of composite shells subjected to thermal and mechanical loads for multi-layered composite shell element with relative degrees-of-freedom adopted to model laminated composite shells. a new criterion of critical heat flux proposed instead of the traditional criterion of critical temperature. **Ajaykumar [2013]** investigated the failure analysis of laminated composite spherical shell used a finite element model based on higher order theory. The proposed 2D finite element model satisfies the parabolic transverse shear stress variation globally and also ensures zero transverse shear stress conditions at the shell top and bottom by using a C0 formulation and avoids the problem of C1 continuity associated with higher order theory.

Sh. H. Hashemi [2012] investigated the closed-form solutions for in-plane and out-of-plane free vibration of moderately thick laminated transversely isotropic spherical shell panels on the basis of Sanders theory without any usage of approximate methods. The effects of various shell parameters like shear modulus ratio of transversely isotropic materials and curvature ratio on the natural frequencies studied. **M. Darvizeh et. at.[2010]** investigated the effect of important structural parameters such as cut-out at apex on the thermal buckling of composite shells with selected boundary condition under uniform and linearly distribution thermal load used finite element method. **S.K. Panda[2014]** investigated the nonlinear free vibration behavior of laminate composite shallow spherical shell under uniform temperature load based on higher order shear deformation theory to count the out of plane shear stress and strain accurately, a nonlinear finite element model proposed to discretize the developed model and the governing equations were derived by Hamilton's principle.

In this paper the thermal buckling behavior of spheroidal spherical composite laminate clamped edges shell structure under uniform temperature will be considered using finite element method are investigated. The material properties are assumed to be linear function of temperature. An analysis is carried out to assess the effect of spherical angle, radius to thickness ratio, orientation of fiber, number of layers and thickness shell on the critical buckling temperature.

Description of Spheroidal Spherical Shell

Figure (1) shows the geometric of composite Spheroidal Spherical Shell with thickness(h) , angle of spherical shell(Φ)and radius of curvature (R).The finite element analysis software package(ANSYS) was used to analyze the thermal buckling of various laminated composite spheroidal spherical shell. The changes to the laminated shells were based on several variables: spherical angle, radius to thickness ratio and orientation of the stitched mat layers. The spherical shell angles were considerate

(30^o,60^o,90^o),shell thicknesses, (h) was used (2,4,6 mm). and the radius to thickness ratio (R/h) used(10,15,25). The several orientation fibers was included in this paper.

Finite Element Analysis

The element used for the laminated shell was used Shell99, which is an 8- node linear layered structural shell element (See Figure(2)). The element has six degrees of freedom at each node: translations in the x, y, and z directions and rotations about the nodal x, y, and z-axes. The Shell 99 element is perfectly suited for composites materials because it allows entry of up to 250 layers. Each layer has its own thickness, material property, and orientation.

Finite Element Formulation

The displacement are expressed as a linear combination of shape function($\vec{q}$)and nodal value (u_N, w_N, v_N)in the following form

$$(U,W,V)=\sum_{N=1}^{k}(u_N\,,w_N,v_N)\vec{q} \qquad (1)$$

Where k is the number of node in each element

By using Finite element method for the spheroidal spherical shell can be obtained the equilibrium equation of the spherical shell under general loading condition may be written as

$$\{[K_{Ls}]\}\{q\}-\lambda\left[K_{Tg}\right]\{q\}=\lambda\{F\} \qquad (2)$$

Where K_{Ls}, K_{Tg} are linear stiffness matrix, thermal geometrical matrix respectively, {F} is the thermal load vector corresponding to the unit temperature, (λ) is a temperature parameter and{q} is the displacement vector.

And to find the critical temperature can be employed the equation

$$[[K_{Ls}]-\vartriangle T[K_{in}]]\{\theta\}=0 \qquad (3)$$

Where $\vartriangle T$ is the critical buckling tempratue and $\{\theta\}$ is the buckling mode, $[K_{in}]$ is the equivalent geometrical stiffness due initial thermal stress in this paper.

Results and Discussion

The spheroidal spherical shell is assumed to be clamped along boundary edge. To evaluate the results of the research compare results of present work with results obtained by Shen [2008]for cylindrical shell and Woo[2007] for conical shell.

In table(1) represents thermal buckling temperature of laminate cylindrical shell under uniform temperature by Shen, changes are possible but not considered in this present study. In additional, the comperes of non-dimensional buckling temperature for laminates (0,90)s conical spherical shell are shown in table (2), by simply boundary condition.

A parametric study intended to supply information on the thermal buckling of composite spheroidal spherical shell subjected to uniform temperature was undertaken. The following properties for materials of spheroidal spherical shell are chosen

(E_1 =172.25GPa, E_2= E_3=6.89GPa, G_1=3.445Gpa G_2= G_3=1.379Gpa, v=0.3, α_1=6.3*10^{-6}/^{o} C, α_2= α_3=18.9*10^{-6}/^{o} C

Table (1): Compression of critical buckling temperature laminate cylinder shell

(E_1 =150GPa,E_2=9GPa,G_1=7.1GPa,v=0.3,α_1=1.1*10^{-6}/^{o}C,α_1=25.2*10^{-6}/^{o}C,Z=L^2/Rt,R/t=200,t=1m

Orientation	z=200		z=500		z=800	
	Shen	**Present**	**Shen**	**Present**	**Shen**	**Present**
(0,90)2s	423.3466	405.725	425.8437	402.378	424.1917	398.517
(±45)2s	1534.531	1493.217	1584.72	1537.217	1655.969	1612.178

Table (2): Compression of non-dimensional critical buckling temperature laminate conical

(E_1 =181GPa,E_2= E_3=10.3GPa,G_1= G_3=7.17GPa, G_2=*6.21GPa,*v=0.28,α_1=0.02*10^{-6}/^{o}C,

α_2= α_3=22.5*10^{-6}/^{o}C ,R/t=25

Semi-vertex angle	Subtended angle	**Woo**	**Present**
30	15	52.741	51.327
60	14	12.517	10.743
120	25	47.321	45.621

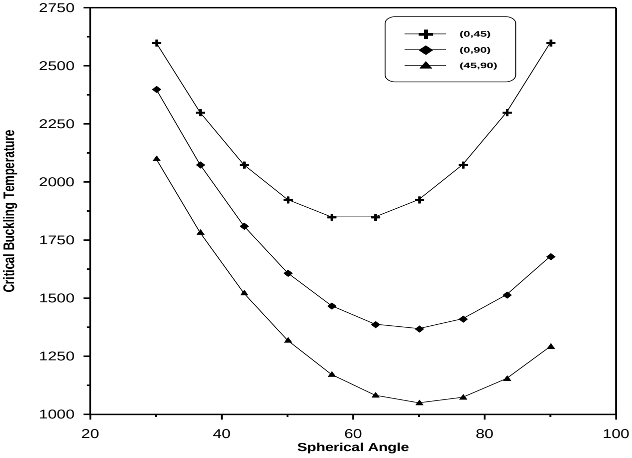

Fig (3): Effect the spherical shell angle on thermal buckling with varies orientation (R/h=10),(h=2mm)

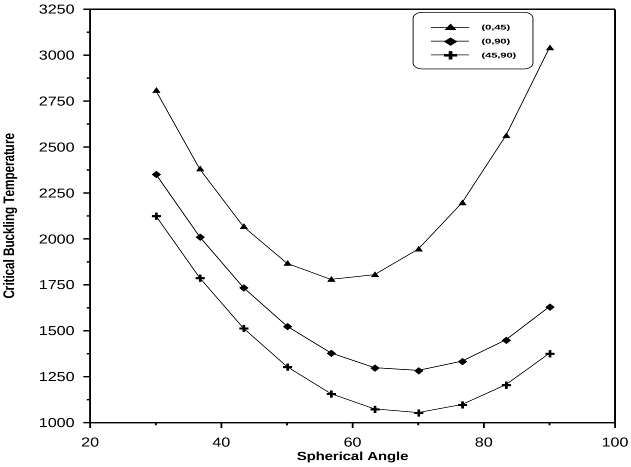

Fig (4): Effect the spherical shell angle on thermal buckling with varies orientation (R/h=25),(h=2mm)

Fig(3,4) Shown that the critical thermal buckling temperature of 2-layers for varies orientation with increasing of spherical angle. Moreover as the thermal buckling temperature of(0,45) has capability better than the (0,90) and (45,90) for same thickness (h=2mm).

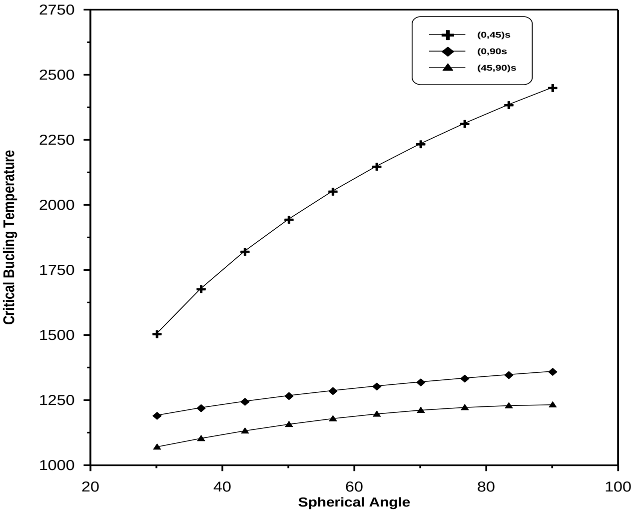

Fig (5): Effect the spherical shell angle on thermal buckling with varies orientation (R/h=10),(h=4mm)

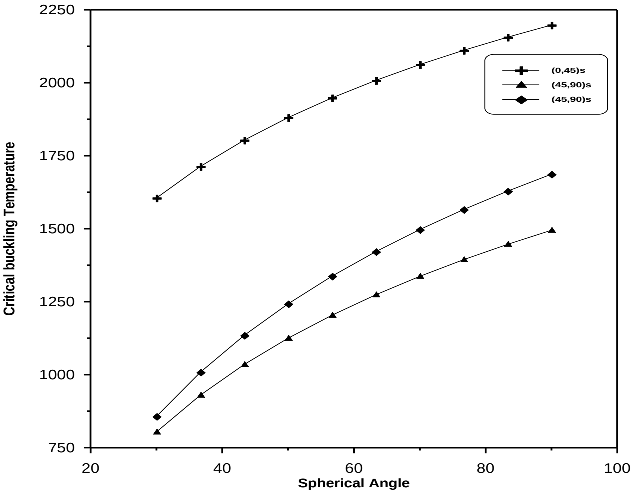

Fig (6): Effect the spherical shell angle on thermal buckling with varies orientation (R/h=15),(h=4mm)

In Fig(5,6) it can be seen that these layers of spherical shell will have different thermal buckling behavior and it increases sharply when the spherical angle increasing. In contrast the thermal temperature (45,90) and(0,90) are relatively smooth.

Fig(7,8) shown that the thermal buckling temperature capability of 8-layers spherical shell better than of 2-layers and 4-layers for the same value of thickness and for (R/h=10,25).

Fig(9) depicts the effect of radius to thickness ratio (R/h=10,15 and 25) on the behavior of thermal buckling spherical shell, as can be observed , the thermal buckling temperature is considerably enhanced as ratio (R/h) increases. Furthermore the increasing in ratio given higher thermal temperature.

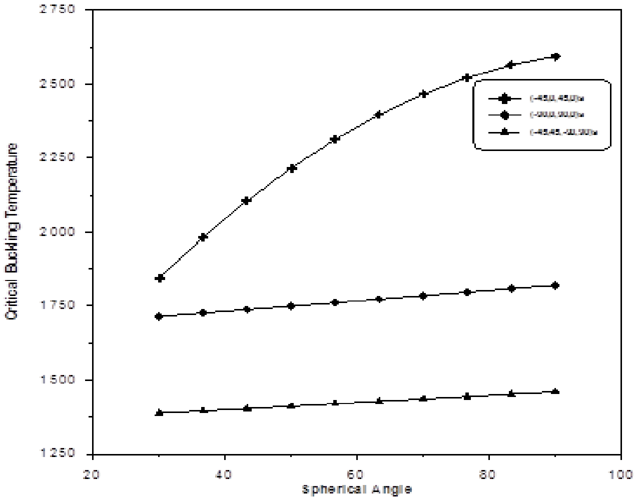

Fig (7): Effect the spherical shell angle on thermal buckling with varies orientation (R/h=10),(h=2mm)

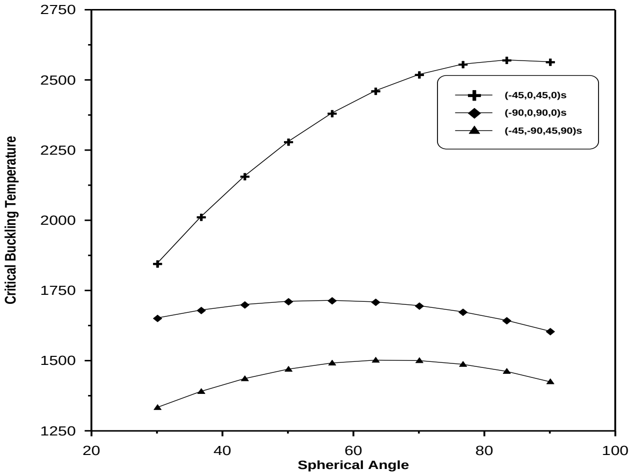

Fig (8): Effect the spherical shell angle on thermal buckling with varies orientation (R/h=25),(h=2mm)

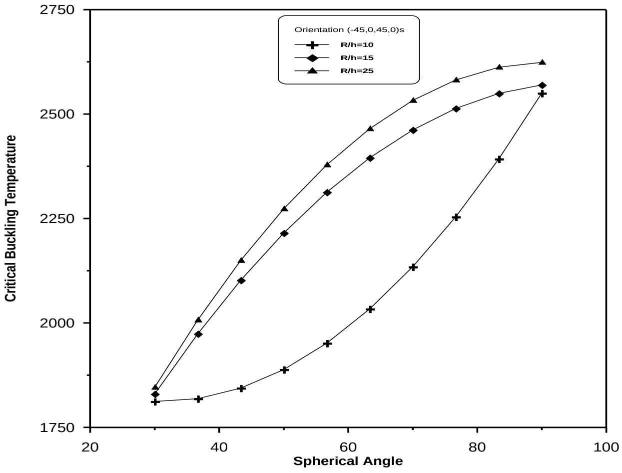

Fig (9): Effect the spherical shell angle on thermal buckling with varies the radius to thickness ratio(N=2),(h=2mm)

Fig(10) shown the effect of thickness spherical shell on the thermal temperature for varies of spherical angle.

Specifically, enhancement the increasing for the spherical angle obtained more thermal temperature as thickness increase.

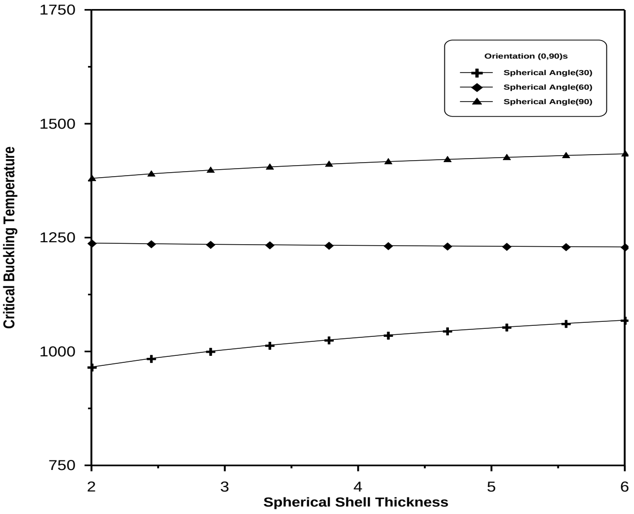

Fig (10): Effect the spherical shell thickness on thermal buckling with varies spherical shell angle(R/h=15)

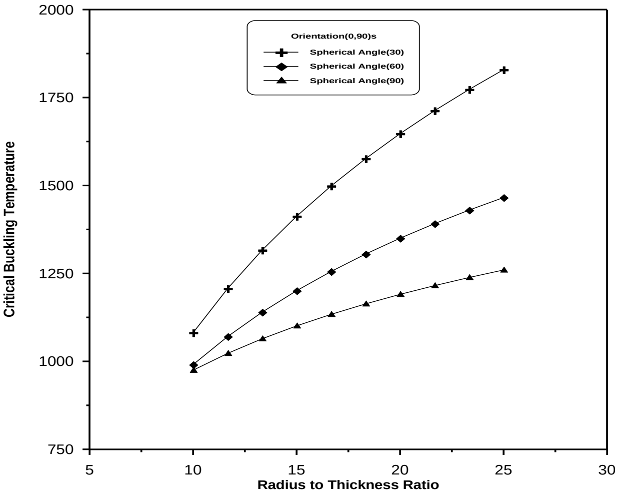

Fig (11): Effect the radius to thickness ratio with varies the spherical shell angle (N=4),(0,90)s

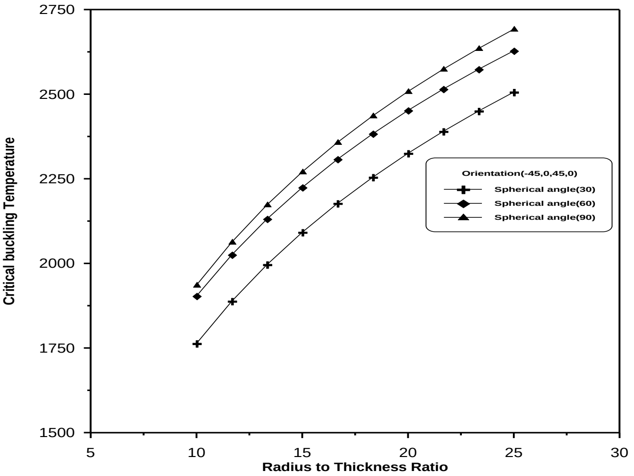

Fig (12): Effect the radius to thickness ratio with varies the spherical shell angle (N=8)

Fig(11,12) shown that the effect of varies spherical angle on thermal temperature with increasing in ratio (R/h) for (4-layers and 8-layers). It can be seen that increasing thermal temperature for (4-layers) with spherical angle decrease for the higher thermal temperature tend to increasing with radius to thickness ratio , but for (8-layers) the behavior is invert for increases spherical angle and ratio. For that, higher thermal temperature for same thickness.

Conclusion

This paper presents an analysis approach to investigated the critical buckling thermal temperature under uniform temperature for clamped edges spheroidal spherical shell using finite element method. Materials properties are assumed to be linear with temperature.

The results show that the behavior of thermal buckling is complex and greatly influenced by the material and geometric parameter. Therefore the following conclusion can be draw:

1-The critical buckling temperature increase as the spherical angle increases

2-As the same thickness, increases in the numbers of layers tend to increases the buckling temperature with increasing the spherical angle.

3-the ordination (0,45),(0,45)s and(-45,0,45,0)s given batter thermal buckling temperature in this study.

4- The study of spheroidal spherical composite shell should be performed at the design stage.

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