IN-PLANE VIBRATION ANALYSIS OF INFLATABLE MEMBRANE STRUCTURE

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ABSTRACT

***Purpose**– The purpose of this paper is to investigate the geometrically nonlinear effect caused by the different pre-stressed in flat thin membrane structure including static and dynamic condition. The governing equation of motion is generated for free transverse vibration of the two dimensional membrane. The finite element approach is presented in which the membrane has to be pre-stressed to act as a structural element. **Design/methodology/approach**– This paper presents a simple two dimensional frame formulation to deal with structures undergoing large motions due to dynamic actions including very thin inflatable structures using the method of separation. **Findings**– The natural frequencies have been investigated for the circular and rectangular shaped flat thin membrane. The result shows that pre-stressed dominates the natural frequency and the oscillations become more and more localized around the region of excitation as the excitation frequency increases for a given pre-stressed value. A good agreement is observed between the finite element and analytical results. **Originality/value**–In space and terrestrial applications, inflatable membrane structures are increasingly used due their light-weight, high strength-to-weight ratio and ease of stowing and deploying capacity. The finite element approach is focused to investigate the geometrically non-linearity of the membrane model using the advanced smart material called kapton.*

Keywords: Finite Element, Material Property, Mode Shape, Natural Frequency, Pre-Stressed, Static Displacement

I INTRODUCTION AND BACKGROUND

Inflatable structures have many potential applications both on Earth and in the space. Even in the field of civil engineering, temporary or emergency structures had been used for a long time, recently, retractable roofs structure of large sports stadia have been made using this light-weight inflatable membrane. These inflatable structures are a viable alternative in aerospace structure design, terrestrial applications and space technology. In space, the former Soviet Union launched the first satellite Sputnik on October 4, 1957 using inflatable deployable structures. In the beginning, all spacecraft were small by virtue of the limited capacity of the launch vehicles but as the spacecraft grew bigger, so did the launch vehicles, but not at the same rate. Large space structures must be designed to be stowed during launch and deployed once on orbit. Hence, instead of using previous electro-mechanical deployment systems, recent efforts of NASA concentrate on the use of inflatable structures for space applications [1].

Over the last few decades, studying the dynamic behaviors of inflatable membrane structures has proven to be a challenging job. Membranes stretched in tension are found in a variety of large gossamer space structures in order to meet the requirement of future space exploration missions, including the James Webb Space Telescope [2]. In recent years many researchers used commercial finite element packages to model and analyze non-linear elastic problems of thin-thickness membrane structures [3]. Many researchers have studied the dynamic characterization of membranes using numerical methods and, when possible, experimental approaches. Numerical methods such as finite difference and boundary elements were used by some researchers to compute vibration modes and frequencies of inflatable dams. The membrane material used in the numerical analysis was assumed inextensible and its weight was neglected in the determination of the equilibrium shape. They found that the membrane's mass density is of little influence on the computed natural frequencies. The effect of frequency between membranes and functionally graded spherical shallow shells of polygonal planform helps to analysis criteria of the boundary condition for the FE model of membrane [4, 5]. Other researchers used finite elements and boundary elements to model and compute natural frequencies and mode shapes of a single-anchor inflatable dam [6]. At present, most researches focused on design and construction of membrane structures received considerable attention recently due to their applications in several engineering areas, including space applications, actuators and sensors; robotics, bio-engineering devices and civil engineering structures [7, 8, 9, 10, and 11]. Also membranes play a significant role in nature due its high load-carrying capacity per unit weight. The analysis of membrane mechanics is an important topic in nonlinear continuum mechanics. However, there is little research on the pretension measurement of membrane structures [12, 13]. The main methods of the pretension measurement include strain method, frequency method, deflection method and "cable analogy" method [14]. If we study the application of frequency method, the vibration theory of membrane must be involved. Many scholars studied about the vibration theory of membrane. Their researches involve the problem of free vibration of a con-focal composite elliptical membrane [15], the problem of fundamental frequency of rectangular membranes with an internal oblique support [16].

The membrane theory is fully accounts for geometric non-linearity. Fully non-linear static analysis is performed for an inflated circular cylindrical Kapton membrane tube under different pressures, and for a rectangular membrane under different tension loads at four corners. Finite-element results show that the shell modes dominate the dynamics of the inflated tube when the inflation pressure is low and that vibration modes localized along four edges dominate the dynamics of the rectangular membrane [17]. Membranes provide for unique structural response due to their extreme thinness and typically low modulus. Hence, the communication of bending information spatially is very weak due to the resultant vanishing flexural stiffness. A membrane by definition has insignificant bending stiffness. From vibration point of view, this in effect decouples domains of the membrane from one another in transverse displacement [18]. The equations of motion of the pre-stretched membrane are derived from the linearized equations, the natural frequencies and mode shapes of the membrane are obtained analytically which show the strong influence of the stretching ratio [19]. The practical occurrences of the nonlinear phenomena are explained by Nayfeh et al. in their series of books [20]. The geometric and the displacement stiffness matrices for a general, thin-walled, beam--column element previously derived in [21, 22]. A fibre type model for the inelastic post-buckling analysis of tubular columns of circular hollow section had been adopted. The cross-section of the tube was divided into a number of elementary areas and the stress on each area calculated [23]. A similar method was presented by the authors for treating geometric and material nonlinear analysis of structures comprising rectangular hollow sections. The influence of various types of residual stress, initial geometric imperfection, load eccentricity and in-elastic behavior of material including the effects of strain unloading were considered in the analysis [24].

In this paper, the geometric nonlinear behavior of the general shaped flat thin membrane is analyzed in terms of the mode shape and natural frequency using the smart materials named, Kapton. The finite element formulation and the mathematical approach is presented for the two dimensional flat thin membrane. This analysis makes more useful in the design of the inflatable structure in space technology. It also discusses the effect of various pre-stressed acting on the thin membrane.

II FINITE ELEMENT AND ANALYTICAL FORMULATION

2.1 Membrane Theory

The plate in which the ratio $a/h \geq 80\ldots.. 100$ where '*a'* is a typical dimension of a plate in a plane and '*h'* is a plate thickness is maintained such plates are referred to as membranes and they are devoid of flexural rigidity. Membranes carries the lateral loads by axial tensile forces (and shear forces) acting in the plate middle surface, these forces are called as membrane forces; they produce projection on a vertical axis and thus balance a lateral load applied to the plate membrane [25], a load free membrane plate is shown in Fig. 1.

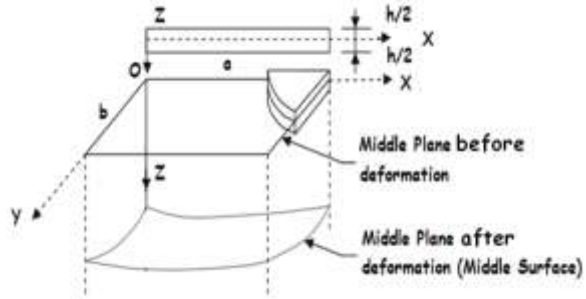


Figure 1: A load free membrane plate

The fundamental assumptions for thin membrane are as follows:

1. The material of the flat thin plate (membrane) remains elastic, homogeneous and isotropic.
2. The deflection (the normal component of the displacement vector) of the mid-plane remains small as compared with the thickness of the membrane structure.
3. The straight lines, initially normal to the middle plane before bending, remain straight and normal to the middle surface during the deformation and the length of such elements is not altered.
4. The middle surface remains unstrained after bending.

2.2 Geometric, Material, Boundary and Loading Condition of Membrane Structure

2.2.1 Geometry

The most commonly used shaped in space technology are circular and rectangular (shown in Fig. 2). The geometric dimensions used for the analysis are given in Table 1.

Table -1: Geometric dimension of flat thin membranes

SN	Membrane Shape	Dimension Parameter (m)		
1	Circle:	Radius : 0.40 ;		Thickness: 0.1e-3
2	Rectangle:	Length : 0.30;	Breadth : 0.40 ;	Thickness: 0.1e-3

(a) 1/4^{rth} Circular shaped **(b) Rectangular shaped**

Figure 2 Flat Thin Membrane Model

2.2.2 Mechanical Properties

There are several smart materials available, but the Kapton polyimide film possesses a unique combination of properties that make it ideal for a variety of applications in many different industries. The ability of Kapton to maintain its excellent physical, electrical and mechanical properties over a wide temperature range has opened new design and application areas to plastic films. Kapton is synthesized by polymerizing an aromatic dianhydride and an aromatic diamine. It has excellent chemical resistance; there are no known organic solvents for the film. Kapton does not melt or burn as it has the highest UL-94 flammability rating: V-0. The outstanding properties of Kapton (see Table 2) permit it to be used at both high and low temperature extremes where other organic polymeric materials would not be functional.

Table 2: Mechanical properties of the Kapton membrane material

Material [26]	Density	Modulus Constant	Poisson's Ratio
Kapton	1420 kg/m^3	2.55e9 N/m^2	0.34

2.2.3 Boundary and loading conditions

In case of circular flat thin membrane model, only a quadrant area is taken into consideration and the symmetrical boundary conditions applied to the quadrant edges. In case of rectangular thin membrane model, the nodes along the consecutive edges are restrained in the Z direction (vertical direction) to simulate simple supports, the nodes along the one edge and other edge are restrained in the Y and X direction because of symmetric and all other nodes have the three degree of freedom. The finite element and analytical results have been compared for both circular and rectangular shaped flat thin membrane for the pre-stress of 10 N/m. The effects of various pre-stress have been used to investigate the geometric non-linearity of the flat thin membrane. Gravity loads are neglected in the simulation.

2.3 Membrane Element (Linear Quadrilateral)

General Membrane Element used in finite element analysis (FEA) tool is M3D4, where 'M' represent membrane, '3' signifies three dimensional and 'D' for degree of freedom and '4' for numbers of nodes. For general membrane elements the positive normal direction is defined by the right-hand rule going around the nodes of the element in the order than that they are specified in the element definition. The rectangular element in Fig. 3 has four nodes and this element used for plane strain analysis will be referred to as M3D4. A much more practical and useful element would be the so-called quadrilateral element, that can have unparalleled edges. The quadrilateral element is to be mapped into the natural coordinates system to become a square element. The shape functions and the integration method used for the rectangular membrane element can be utilized.

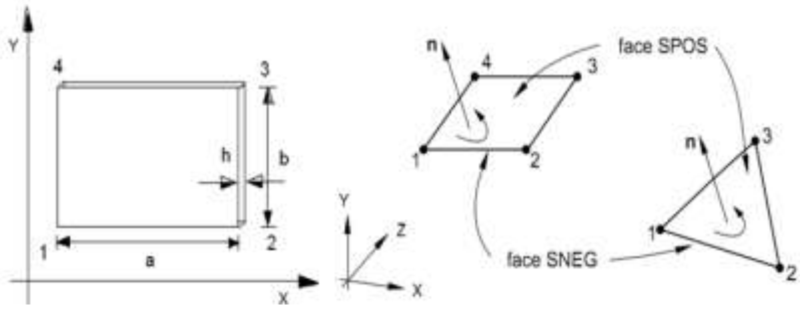


Figure 3 Four Quadrilateral Element and Positive normal for general membrane

2.4 Coordinate Mapping

Fig. 4(a) shows a 2D (two dimensional) domain with the general shape in which a domain quadrilateral element is to be divided with four straight but unparallel edges, considering a quadrilateral element with four nodes numbered 1, 2, 3 and 4 in a counter-clockwise direction.

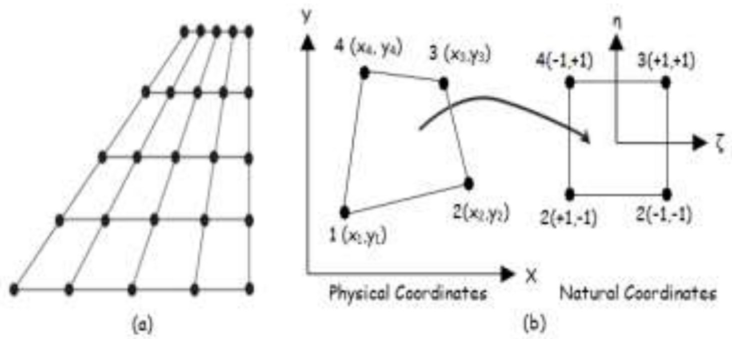


Figure 4 (a) 2D domain meshed by quadrilateral element. (b) Coordinate mapping between coordinate system.

The coordinates for the four nodes are indicated in Fig. 4(b) in the physical coordinate system. The physical coordinate system can be the same as the global coordinate system for the entire structure. As there are two DOFs at a node, a linear quadrilateral element has a total of eight DOFs, like the rectangular element. A local natural coordinate system *(ξ,η)* with its origin at the centre of the squared element mapped from the global coordinate system is used to construct the shape functions, and the displacement is interpolated using the equation.

$$U^h(\xi, \eta) = N(\xi, \eta)de \quad (1)$$

Eq. (1) represents a field variable interpolation using the nodal displacements.

Using a similar concept, the coordinates x and y can be interpolated from the nodal coordinates using the shape functions, which are expressed as functions of the natural coordinates. This coordinate interpolation is mathematically expressed as

$$X(\xi, \eta) = N(\xi, \eta)\, X_e \quad (2)$$

where, X is the vector of the physical coordinates,

$$X = \begin{Bmatrix} x \\ y \end{Bmatrix} \tag{3}$$

and N is the matrix of shape functions

$$N = \begin{Bmatrix} N_1 & 0 & N_2 & 0 & N_3 & 0 & N_4 & 0 \\ 0 & N_1 & 0 & N_2 & 0 & N_3 & 0 & N_4 \end{Bmatrix} \tag{4}$$

where, the shape functions *Ni* (i = 1, 2, 3, 4) are the shape functions corresponding to the four nodes of the quadrilateral element and X_e is the physical coordinates at the nodes of the element, given by

$$X_e = \begin{Bmatrix} x_1 \\ y_1 \\ x_2 \\ y_2 \\ x_3 \\ y_3 \\ x_4 \\ y_4 \end{Bmatrix} \tag{5}$$

Eq. (2) can also be expressed explicitly as:

$$x = \sum_{i=1}^{4} N_i(\xi, \eta) x_i \tag{6}$$

$$y = \sum_{i=1}^{4} N_i(\xi, \eta) y_i \tag{7}$$

where, Ni is the shape function.

2.5 Strain Matrix

After mapping is performed for the coordinates, the strain matrix B is evaluated. In matrix form written as

$$\begin{bmatrix} \partial N_i / \partial \xi \\ \partial N_i / \partial \eta \end{bmatrix} = J \begin{bmatrix} \partial N_i / \partial x \\ \partial N_i / \partial y \end{bmatrix} \tag{8}$$

where J is the Jacobian matrix defined by

$$J = \begin{bmatrix} \partial x / \partial \xi & \partial y / \partial \xi \\ \partial x / \partial \eta & \partial y / \partial \eta \end{bmatrix} \tag{9}$$

From Eq. (6), (7) and (9), J is:

$$J = \begin{bmatrix} \partial N_1 / \partial \xi & \partial N_2 / \partial \xi & \partial N_3 / \partial \xi & \partial N_4 / \partial \xi \\ \partial N_1 / \partial \eta & \partial N_2 / \partial \eta & \partial N_3 / \partial \eta & \partial N_4 / \partial \eta \end{bmatrix} \begin{bmatrix} x_1 & y_1 \\ x_2 & y_2 \\ x_3 & y_3 \\ x_4 & y_4 \end{bmatrix} \tag{10}$$

The Equation B = LN used to compute the strain matrix B.

2.6 Element Matrices

Once the strain matrix B has been obtained, it can proceed to evaluate the element matrices. The elemental stiffness matrix k_e for 2D solid elements can be obtained using

$$k_e = \int_{-1}^{+1}\int_{-1}^{+1} hB^T cB \det|J| \, d\xi . d\eta \tag{11}$$

Where, $B^T cB \det|J|$ is the fractional and polynomial function of strain matrix.

Also, the elemental mass matrix m_e given by

$$m_e = \int_{-1}^{+1}\int_{-1}^{+1} h\rho N^T N \det|J| \, d\xi . d\eta \tag{12}$$

Where, B is strain matrix, Where, $N^T N \det|J|$ is the polynomial functions of shape matrix.

The shape functions [27] used to interpolate the coordinates in Eq. (6) and Eq. (7) are the same as those used for interpolation of the displacements. Such an element is called an iso-parametric element.

III MEMBRANE VIBRATION

A membrane is a thin plate subjected to pre-stress or tension and has negligible bending resistance. Thus, a membrane bears the same relationship to a plate as a string bears a beam. Textile covers and roofs, aircraft and space structures, parachutes, automobile airbags, sails, windmills, human tissues and long span structures are the examples of membrane [28].

To derive the equation of motion of thin flat membrane, consider the membrane to be bounded by a plane curve S in the *XY* plane, as shown in Fig. 5. Let *f(x,y,t)* denote the pressure loading acting in the *Z* direction and *P* the intensity of tension at a point that is equal to product of the tensile stress and the thickness of the membrane.

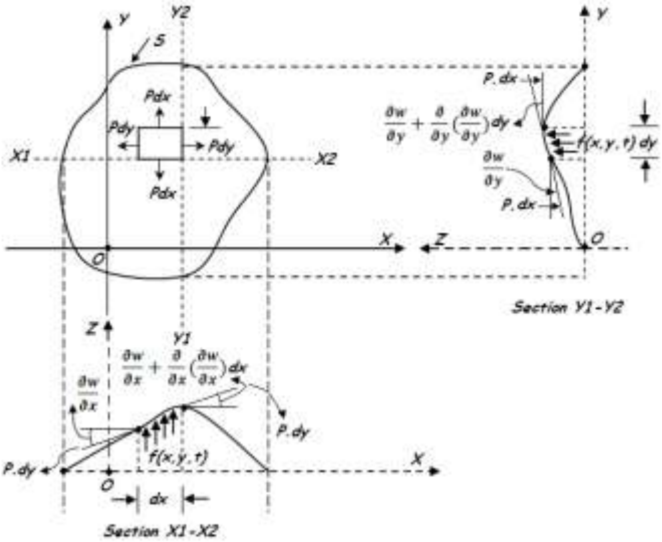


Figure 5 A membranes under the uniform tension or pre-stressed.

The magnitude of *P* is usually constant throughout the membrane. An elemental area is considered as *dx dy*. Forces of magnitude *Pdx* and *Pdy* act on the sides parallel to the *Y* and *X* axes respectively as shown in Fig.

5.The net forces acting along the Z direction due to these forces are $\left(P \frac{\partial^2 w}{\partial y^2} dx\ dy \right) and \left(P \frac{\partial^2 w}{\partial x^2} dx\ dy \right)$. The pressure force along the Z direction is $f(x, y, t)\ dxdy$ and the inertia force is $\rho(x,y) \frac{\partial^2 w}{\partial t^2} dx\ dy$.

where, $\rho\ (x,y)$ is the mass per unit area. The equation of motion for free transverse vibration of the membrane can be obtained as;

$$P \left(\frac{\partial^2 w}{\partial x^2} + \frac{\partial^2 w}{\partial y^2} \right) = \rho \frac{\partial^2 w}{\partial t^2} \tag{13}$$

The above equation can be expressed as;

$$P \nabla^2 w = \rho \frac{\partial^2 w}{\partial t^2} \tag{14}$$

Where, $\nabla^2 = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2}$ is the Laplacian operator.

3.1 Non-Linear Boundary Condition

Since, the equation of motion Eq. (15) involves second order partial derivatives with respect to each of t, x and y. it is needed to specify two initial conditions and four boundary condition (boundary condition may varies depending on shape and size) to find a unique solution of the problem [29]. Usually, the displacement and velocity of the membrane at $t=0$ are specified as $w_o(x, y)$ and $\dot{w}_o(x, y)$ Hence, the initial conditions are given by,

$$w(x, y, 0) = w_0(x, y) \tag{15}$$

$$\frac{\partial w}{\partial t}(x, y, 0) = \dot{w}_0(x, y) \tag{16}$$

The boundary conditions are as follows:

1. If the membrane is fixed at any point (x_1, y_1) on a segment of the boundary, then;

$$w(x_1, y_1, t) = 0 \qquad t \geq 0 \tag{17}$$

2. If the membrane is free to deflect transversely (in the z direction) at a different point (x_2, y_2) of the boundary, then the force component in the Z direction must be zero.

$$P \frac{\partial w}{\partial n}(x_2, y_2, t) = 0 \qquad t \geq 0 \tag{18}$$

where, $\partial w / \partial n$ represents the derivative of w with respect to a direction n normal to the boundary at point (x_2, y_2).

The free vibration solution of the thin flat membrane can be obtained by using the method of separation of variables $w(x, y, t)$ can be assumed as;

$$w(x,y,t) = W(x,y)T(t) = X(x)Y(y)T(t) \tag{19}$$

By using the equation of motion Eq. (15), we obtain,

$$\frac{d^2X(x)}{dx^2} + \alpha^2 X(x) = 0 \tag{20}$$

$$\frac{d^2Y(y)}{dy^2} + \beta^2 Y(y) = 0 \tag{21}$$

$$\frac{d^2T(t)}{dt^2} + \omega^2 T(t) = 0 \tag{22}$$

Where α^2 and β^2 are constants related to ω^2 as follows:

$$\beta^2 = \frac{\omega^2}{C^2} - \alpha^2 \quad \text{where,} \quad C^2 = \left(\frac{P}{\rho}\right) \tag{23}$$

The solutions of the above Eq. (20) to Eq. (22) are given by;

$$X(x) = C_1 Cos\ cx + C_2 Sin\ \alpha x \tag{24}$$

$$Y(y) = C_3 Cos\ \beta y + C_4 Sin\ \beta y \tag{25}$$

$$T(t) = A\ Cos\ \omega t + B\ Sin\ \omega t \tag{26}$$

Where, the constants C_1, C_2, C_3, C_4 and A, B can be determined from the boundary conditions. The various constant points (x_i,y_j) utilized to solve the general flat thin membrane are listed below as shown in Table – 3.

Table 3 values of constant for points *(xi, yi), i= 1, 2, 3….*

x	y	α	β
0	*0.1*	-	$\pi/0.1$
0	*0.2*	-	$\pi/0.2$
0.1	*0.1*	$\pi/0.1$	$\pi/0.1$
0.1	*0.2*	$\pi/0.1$	$\pi/0.2$

The results for the various shaped flat thin membrane can be found out by using the MATLAB and tabulated in the next section.

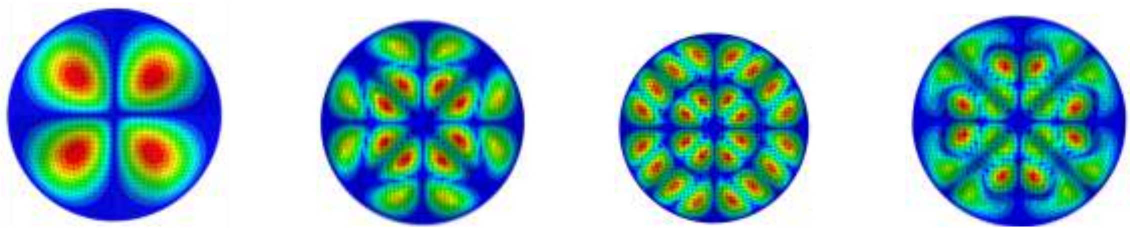
IV RESULTS AND DISCUSSION

The flat thin membrane of circular shaped having radial dimensions of 0.4 m with the thickness of 0.1e-3 m is considered. The membranes were made up of Kapton film due to its outstanding properties at both high and low temperature extremes, where other organic polymeric materials would not be functional. Using the above mentioned mechanical properties and the boundary conditions, it has been focused on the effects of pre-stressed of 10 N/m and the natural frequencies analysis. In the case of circular flat thin membranes, because of the uniform thickness and symmetric geometry the mode shapes appear in pairs as shown in the Fig. 6. From Table 4, it is observed that in the First Mode#1, the high natural frequency difference appeared when 10 N/m is applied compared to the Mode#2 and then the lower natural frequency difference occurs in the successive mode shapes. It is happened due to the oscillations become more and more localized around the region of excitation as the excitation frequency increases for a given pre-stressed value. In particular, it has been found that under the same pre-stressed value at the particular node, the excitation region is much smaller than the membrane dimensions. These frequency disturbances among the nodes varies even due to other factors such added mass or atmospheric air pressure. The absolute errors obtained are very much less and tabulated in Table 4.

Table 4 Analytical and FEA result of circular flat thin membrane

SN	Mode shape No.	Result of 1/4th model of Circular flat thin membrane using Kapton film with Pre-stressed of 10 N/m.		
		FE Result (Hz)	Analytical (Hz)	Absolute error
1	1	9.289	9.478	0.189
2	2	13.226	13.986	0.760
3	3	14.431	14.707	0.276
4	4	17.316	17.797	0.481
5	5	17.981	18.169	0.188

(i) Few mode shape frequency of circular flat thin membrane:



Mode 1 # 9.498 Hz Mode 5 # 18.385 Hz Mode 7 # 21.707 Hz Mode 9 # 23.296 Hz

Figure 6 Mode shape of circular shaped flat thin membrane at 10 N/m pre-stressed.

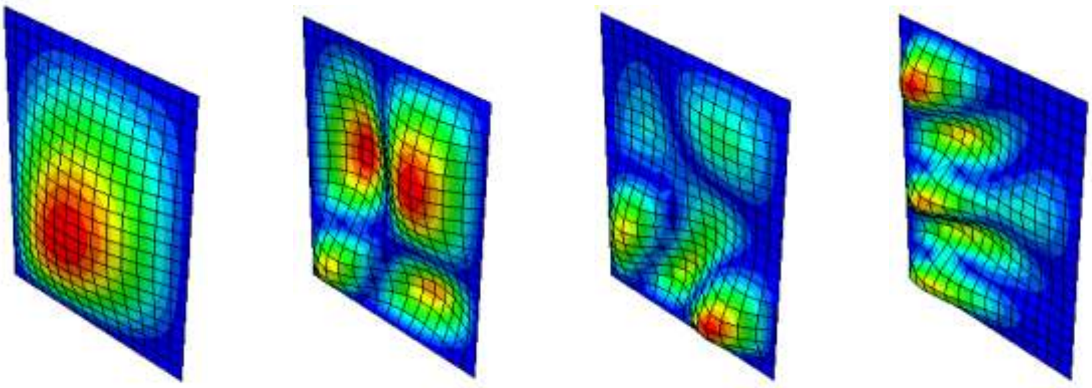
Table 5 shows the good agreement between the FE results and analytical one of the rectangular flat thin membrane using Kapton material with Pre-stressed of 10 N/m. Using the mechanical properties given in the Table 2 and the boundary conditions mentioned in section 2.2.3, it has been observed that most nodes are local vibration modes around the edges except a few global modes.

Table 5 Analytical and FEA results of rectangular flat thin membrane.

SN	Mode shape No.	Result of Rectangular flat thin membrane using Kapton with pre-stressed -10 N/m.		
		FE Result (Hz)	Analytical (Hz)	Absolute error
1	1	21.511	21.977	0.466
2	2	29.381	29.970	0.589
3	3	35.956	36.423	0.467
4	4	38.770	39.121	0.351
5	5	41.790	41.961	0.171

These local modes are due to the non uniform loading condition over the entire membrane as the four edges are under the very small pre-stressed value as shown in Fig. 7. In the mode 1, it is appeared the weaker section at the centre as the local vibration modes dominates over the global one, where as in the mode 5 or in other successive modes it is observed that the oscillations become more and more localized around the region of excitation. Hence, the excitation frequency increases for a given pre-stressed value with minimum difference. The non uniformity in the mode shapes obtained due to the non-symmetric shape.

(ii) Few Mode shape frequency of Rectangular flat thin membrane:



Mode 1# 21.511 Hz Mode 5# 41.790 Hz Mode 7# 48.059 Hz Mode 9# 56.025 Hz

Figure 7 Mode shape of Rectangular flat thin membrane at 10 N/m pre-stressed.

The wave propagation of the rectangular shaped flat thin membrane showing the maximum range of natural frequency in 3D form as shown in Fig. 8.

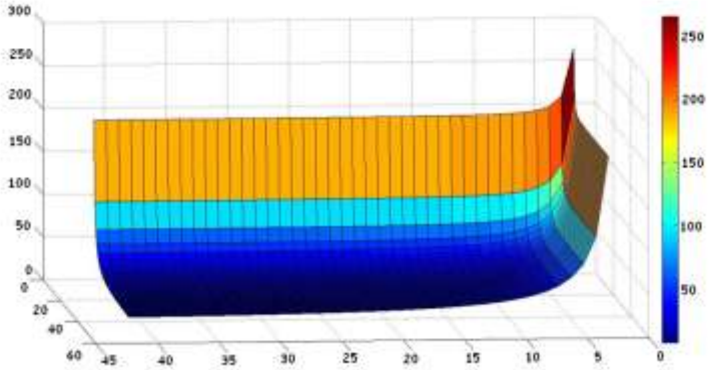


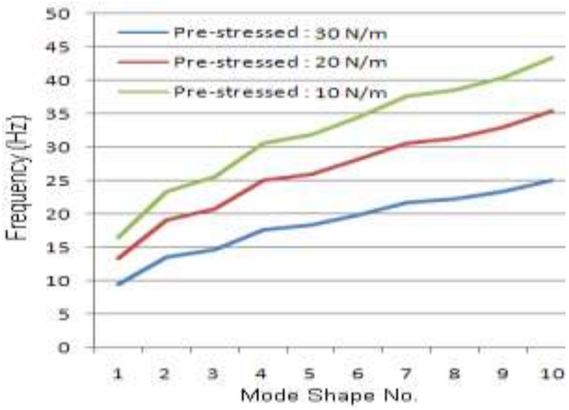
Figure 8 Frequency propagation of the rectangular flat thin membrane model

The results obtained due to various pre-stressed for the particular shape of the flat thin membrane are given Table 6. It is observed that as pre-stressed value increases the difference of natural frequency decreases for the successive mode shape except first one. The enormous frequency difference between the first two mode shapes occurs due to the random oscillations around the region of excitation. The Fig. 9 and Fig. 10 shows the variations of the various pre-stressed.

Table 6 Frequency values using various pre-stressed of general flat thin membrane

Mode No.	Various Pre-stressed Value (N/m)					
	Circular flat thin Membrane (Hz)			Rectangular flat thin Membrane (Hz)		
	10	20	30	10	20	30
1	9.498	13.432	16.450	21.511	30.421	37.257
2	13.524	19.125	23.423	29.381	41.551	50.889
3	14.755	20.867	25.556	35.956	50.849	62.276
4	17.705	25.039	30.666	38.770	54.828	67.150
5	18.385	26.000	31.843	41.790	59.100	72.381
6	19.971	28.243	34.591	47.737	67.510	82.682
7	21.707	30.698	37.597	48.059	67.965	83.239
8	22.243	31.456	38.525	49.466	69.955	85.676
9	23.396	33.086	40.522	56.025	79.231	97.037
10	25.075	35.461	43.430	56.651	80.116	98.121

The following graphs show the result variations using the different pre-stressed values.



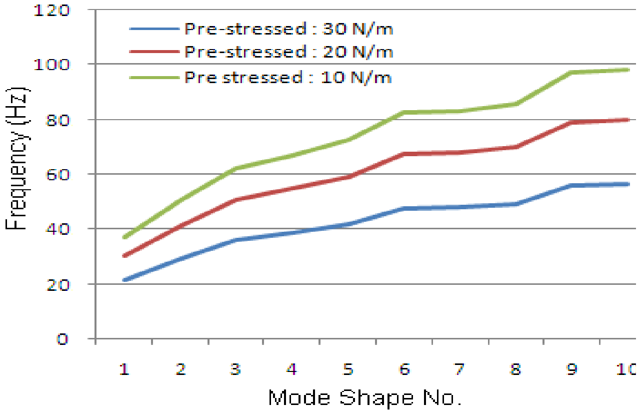


Figure 9 Mode shape vs Natural Frequency of circular shaped flat thin membrane using various pre-stressed loading condition.

Figure 10 Mode shape vs Natural Frequency of rectangular shaped flat thin membrane using various pre-stressed loading condition.

V CONCLUSION

In the field of engineering application, inflatable (thin membrane) structures with very light materials are demandable due to non flexural stiffness and optimally within structural member subjected to pre-stressed rather than bending or moments. In this paper, it has been observed that as the pre-stressed value get increased the natural frequency decreases. Since, the natural frequency is the important criteria while designing the inflatable structure, the simulation shows the curved profile shaped plays an important role as compared to the straight profile structure. The spread of deformation spatially across the membrane depends on the membrane tension and local curvature. During the static analysis, it is also found the frequency disturbance among the nodes varies even due to other factors such added mass or atmospheric air pressure. In particular, it is found that under the same pre-stressed value at the particular node, the excitation region is much smaller than the membrane dimensions. The oscillations become more and more localized around the region of excitation as the excitation frequency increases for a given pre-stressed value. There is a good agreement between the finite element results and analytical results. In this paper, the dynamic behavior of the general shaped flat thin membranes is analyzed in terms of the mode shape and natural frequency using the smart materials named, Kapton. This analysis makes more useful in the design of the inflatable structure in space technology.

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