ANALYSIS OF LAMINATED TUBULAR STRUCTURE UNDER TORSION

by

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Presented to the Faculty of the Graduate School of

The University of Texas at Arlington in Partial Fulfillment

of the Requirements

for the Degree of

MASTER OF SCIENCE IN AEROSPACE ENGINEERING

THE UNIVERSITY OF TEXAS AT ARLINGTON

December 2011

ACKNOWLEDGEMENTS

I would like to express my sincere appreciation and gratitude to my supervising professor Dr. Kent L. Lawrence who gave me the knowledge of Finite Element Method which importantly helps me to conduct my thesis. Moreover, I wish to extend my gratitude to my co-advisor, Dr. Wen S. Chan. He has been a source of inspiration and guidance throughout my composite work. Both of them gave me lots of useful knowledge about composite material and programming using commercial software, ANSYS which I had never used before. Not only for my thesis but that knowledge is also very valuable for me in the future work. Without them support and guidance, this thesis would not been accomplished.

I also would like to thank Dr. Seiichi Nomura for spending time to be my thesis committee. Thanks to his comments and suggestions for my thesis as well.

I wish to thank my friends in CAD lab who help me passed through problems using ANSYS V.11 and helping me about English language in my thesis. Without them, my life would be much harder to get through those problems. I would like to thank all of my Thai friends who always encourage me during the time I was conducting my thesis. Without them in the US, my life would not been meaningful and happy as I always am.

Lastly, I particularly thank my parents and my family who always give love and encouragement to me. Especially, thank my parents who have been supporting for all of my studying expense. Without their attentiveness, my life would not been great like this.

November 18, 2011

ABSTRACT

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Laminated composite shells in particular are prominent in bearing various types of loads and are hence used in many engineering structures. The analysis of laminated composites is quite complicated since the material behavior is anisotropic, which gets further intensified in the analysis of complex structures like tubular structures. Finite element method is a useful method for evaluating and conducting the behavior of thin laminated tubular structure subjected to torsion.

In this study, the behavior of shear stress versus angle along the laminated tubular structure cross section was conducted in varies radius ratio which are 1, 0.8, 0.6, 0.4, and 0.2 on different fiber orientation which are symmetry and antisymetry. The results reveal an unsteady behavior pattern on the high curvature section that effected when the radius ratio is reducing to a small number. However, in the high radius ratio the tubular structure shear stress is identical to laminate theory

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CHAPTER 1

INTRODUCTION

1.1 Composite Material Overview

As composite material becomes more and more cost effective, they are beginning to replace many conventional materials in everyday application. For example, the automotive industry is being forced to design lighter car, to increase fleet gas mileage. Composite shafts, for example, golf shafts head to graphite fiber material, commonly called “Broadgood”. Aerospace engineering is also changing. Aero planes have traditionally been made out of metal, usually aluminum alloys; now however, engineers are increasingly working with carbon fiber composites. For example, A380, the world’s largest passenger aircraft, that these materials have been deployed extensively in primary load carrying structure. The A380 uses composite materials in its wings, which helps enable a 17% lower fuel use per passenger than comparable aircraft.

Laminated composite shells in particular are prominent in bearing various types of loads and are hence used in many engineering structures. The analysis of laminated composites is quite complicated since the material behavior is anisotropic, which gets further intensified in the analysis of complex structures like shells. Laminated composite shells are used in fuselage structures, missiles and spacecraft, jet nozzles etc.

The behavior of material such as a stress concentration or modulus stiffness is important for engineering design because of these environments are guiding an engineer to reach a successive design. Unlike isotropic materials for which the applied normal stress (or shear stress) induces only the normal (or shear) stress, all three displacement components and most of the six stress components are nonzero for general anisotropic materials.

Due to the complexity of the governing equations, the availability of variety of elasticity solutions for laminated composite shells has been scarce in comparison to laminated plates. This paper followed laminated shell theories to calculate stress and stiffness modulus of tubular (ESP. circular) tube made of fiber reinforced composites subjected to torsion.

1.2 Literature Review

In 1968, Lekhniskii [1] used anisotropic elasticity with complex variable method to give close from solution to compute stress distributions around a circular hole in an infinite anisotropic plate. Average laminate elastic properties to compute average stress distribution in the infinite size laminate with hole was used.

In 1971, Whitney [2] developed a shell theory known as Vlasov-Ambartsumyan and applied in order to calculated stresses in anisotropic and laminated cylinders subjected to combination of axial load, torsion, and internal pressure. Comparison to results obtained from exact elasticity theory shows that the shell equations are capable of predicting, with a reasonable degree of accuracy, the large stress gradients found in highly anisotropic tubes.

In 1996, Loughlan and Ata [3] introduced a simple engineering theoretical approach which is able to predict the initial constrained torsional response of a specific class of thin-walled, single-cell, graphite fibrous composite box beams. Comparisons between theory and finite element and between theory and experiment are illustrated in a good agreement.

In 1996, Liu [4] has developed a theory for nonlinear bending of symmetrically laminated, cylindrically orthotropic, shallow conical shells subjected to an axisymmetrically distributed load. Transverse shear effects were also included in his model.

In 1997, Chan and Demirhan [5] derived a closed form analytical solution for evaluation of bending stiffness of composite tubes. Both plate and shell approaches were developed. A conventional approach, which in used the smear property is also used for comparison. They concluded that the laminated shell approach gave a better result than laminated plate approach when the radius of the circular tube became smaller. Their result reveals that for a small radius, the conventional approach could give an error up to 50% comparing with 11.5% for plate approach and 1.3% for the shell approach.

In 1999, Chouchaoui and Ochoa [6] introduced a general analytical model developed for the stress and displacement of an assembly of several coaxial-laminated hollow circular cylinders that were subjected to internal/extensional pressure, tensile, torsion and bending load.

In 2000, Tarn and Wang [7] presented a developed state space approach to extension, torsion, bending, shearing and pressuring of laminated composite tubes. An analysis of the tube subjected to uniform tractions on the inner and outer surfaces, and axial force, a torque and bending problem at the ends was conducted. The characteristics of the Eigen solution of the system matrix are used to advantage in deriving the fundamental transfer matrices.

In 2001, Lin and Chan [8] developed a simplified closed form expression of stiffness matrices for elliptical composite tube. The results show that the bending stiffness of the tube and the layer stresses are in an excellent agreement with the results obtained from finite element method.

In 2003, Correia and Herskovits [9] have presented a numerical method for the structural analysis of laminated conical shells using a quadrilateral isoperimetric element based on higher order shear deformation theory. The model developed can be used to perform static analysis with arbitrary boundary conditions and loads and for solving Eigen values problems.

In 2007, Rao [10] developed the closed form expressions for determining the displacement and twisting angle of tapered composite tubes. The analytical expressions are developed based on the modified laminated plate theory which includes the tubular wall curvature of the laminate. It is found that the axial deformation and the twisting angle calculated by the current method agree well with the results obtained from the finite element method.

1.3 Objectives of this study

The primary objective of the study is to investigate the behavior of stress along the cross section of laminated tubular structure subjected to torsion. Both simple approximate analytical method and finite element method were used. Five laminates with different stacking sequences ranging from symmetrical and balanced laminate, antisymmetrical and balance and unsymmetrical and balanced were studied. The tube with a constant of half major axis,0.5 in and its half minor axis, ranging from 0.5 to 0.1 in.

1.4 Outline of the Thesis

In chapter 2, the convectional thin wall and laminated plate theory under torsion are described, respectively.

Chapter 3 describes the finite element model procedures. The geometry, boundary condition, and loading condition of the tubular structure are included. The developed finite element model is validated at the end of the section.

Chapter 4 presents the comparison results of stress X, Y, Z and shear stress YZ versus angle along the tubular cross section. The behavior of stresses on laminate stacking sequence in described.

Conclusion and future study are presented in chapter 5.

CHAPTER 2

THETHEORY OF THIN-WALLED UNDER TORSION AND LAMINATED SHELL

In this chapter, an analytical equation of thin-walled tubes under torsion and analytical solution for calculating stiffness matrix for laminate plate are reviewed.

2.1 Thin-Walled Tubes Subjected to Torsion

The first assumption is that the wall tube is thin when compared to the tube radius. First rule is the thickness should be less than 10% of the smallest overall external dimension. Second, tube does not have any cut or slice. In other words, it is continuous around the radius. The tube does not need to be circular but it should not have severe reverse curvature. Some acceptable cross sections are shown in the diagram at the left. Also, the thickness does not need to be constant.

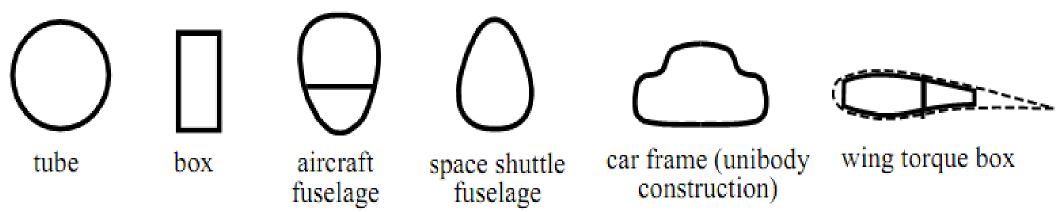


Figure 2.1 Examples of Thin-Walled Tube Cross-Sections

2.1.1. Shear Flow in Thin-Walled Tubes

To analyze thin-walled tubes, the concept of shear flow, q, needs to be understood. When a moment (or torque) load, T, is applied to a thin-walled tube, the load is distributed around the tube as a shear stress, τ. But this is a difficult value to deal with since it is not constant. A better value is the shear flow, which is simply the stress multiplied by the changing thickness, t.

$$q = \tau T \tag{2.1}$$

The shear flow multiplied by an arc length of the tube, ds, will give a force. This force, dF, causes a moment, dT, about the tube center. Summing all the moments caused by all the differential lengths, ds, will give the total applied moment, T.

$$\oint_s \; r\,dF = \oint_s \; r\,qdS = T \tag{2.2}$$

For a small element, the area of the triangular section, dA_o, is approximately,

$$dA_0 = 0.5\,rdS \tag{2.3}$$

The total area can be calculated by integration over the total tube cross section length, S, giving,

$$\oint_s \; r\,dS = 2A_0 \tag{2.4}$$

For a closed section of beam, shear flow is a constant along its contour. Hence, equation 2.2 can be rewritten as;

$$q = \frac{T}{2A_0} \tag{2.5}$$

2.1.2. Angle of Twist in Thin-Walled Tube

The angle of twist for a closed thin tube with a noncircular cross section is developed by using energy methods along with the previous equations. First, at a small element from a typical tube that is undergoing deformation, the stored strain energy can be found from using the basic concept that energy is equal to a force operating through a distance, U = F • L. For the small infinitesimal element, ds by dx, the force causing the deformation is dP, q ds. At the base, the deformation is zero and at the free end is (γ ds). Thus the average deformation is simply (γ dx)/2. The total strain energy for the element is

$$dU = [dP]\,[0.5\,(\gamma\,ds)] = (q\,ds)(\gamma\,ds)/2 = q\,\gamma\,(ds)2/2 \qquad (2.6)$$

From Hooke's law

$$\gamma = \tau/G \qquad (2.7)$$

And,

$$\tau = q/t \qquad (2.8)$$

Substitute γ and τ into the energy equation gives,

$$dU = \frac{q^2}{2Gt}\,dsdx \qquad (2.9)$$

Integrated over the length of the tube, L, and around the circumference of the tube, this gives,

$$U = \frac{q^2}{2G}\int_0^L\left(\oint_S \frac{ds}{t}\right)dx = \frac{q^2L}{2G}\oint_S \frac{ds}{t} \qquad (2.10)$$

Apply simply moment $U = T/2$ where is the angle of twist, gives,

$$\frac{T\theta}{2} = \left(\frac{T}{2A_0}\right)^2\frac{L}{2G}\oint_S \frac{ds}{t} \qquad (2.11)$$

Rearranging gives,

$$\theta = \frac{TL}{4GA_0{}^2}\oint_S \frac{ds}{t} \qquad (2.12)$$

For constant thickness we got

$$\theta = \frac{TL}{4GA_0{}^2 t} \tag{2.13}$$

2.2 Laminated Plate Theory

The laminated tube considered in a uniform tube, with tubular cross section with an outer radius R_o, inner radius R_i and a length L. The length of the tube is sufficiently larger than its radii. Hence the tube considered is a long tube. In all the derivations the basic assumption of 'Plane remains plane after deformation' is made.

2.2.1. Stress-Strain Relationship of Thin Lamina

In most practical applications of composite material, the laminates are considered as a thin and loaded along the plane of laminates. Since each lamina is a thin layer, one can treat a lamina as a plane stress. This simplification immediately reduces the 6x6 stiffness matrix to 3x3 one.

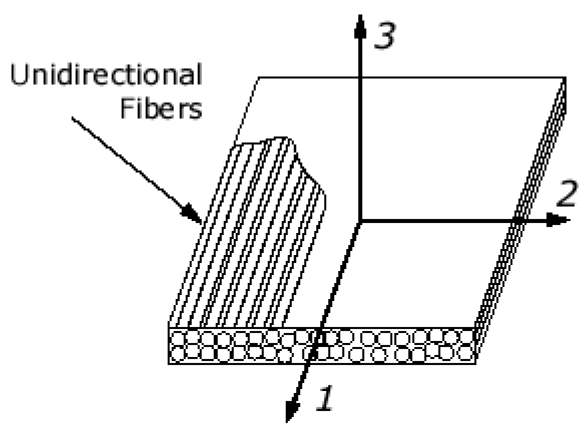


Figure 2.2 Example of Lamina

The thin layer composite is assumed to be under a state of plane stress. This implies that all stress components in the out of plane direction are zero. That is,

$$\sigma_3 = 0$$

$$\tau_{23} = \tau_4 = 0$$

$$\tau_{13} = \tau_5 = 0$$

(2.14)

Since each lamina is constructed by unidirectional fibers bonded by a matrix, it can be considered as an orthotropic material. Thus, the stress-strain relations on the principal axes of the laminate plane can be expressed by the compliance matrix [S] as

$$[\varepsilon] = [S][\sigma]$$

$$\begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \gamma_{12} \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} & 0 \\ S_{21} & S_{22} & 0 \\ 0 & 0 & S_{66} \end{bmatrix} \begin{bmatrix} \sigma_1 \\ \sigma_2 \\ \sigma_{12} \end{bmatrix}$$

Or

$$\begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \gamma_{12} \end{bmatrix} = \begin{bmatrix} \frac{1}{E_1} & \frac{\upsilon_{12}}{E_1} & 0 \\ \frac{\upsilon_{21}}{E_2} & \frac{1}{E_2} & 0 \\ 0 & 0 & \frac{1}{G_{12}} \end{bmatrix} \begin{bmatrix} \sigma_1 \\ \sigma_2 \\ \sigma_{12} \end{bmatrix}$$

(2.15)

The reduce stiffness matrix [Q], which are function of the elastic constants, can be expressed as such that

$$[\sigma] = [Q][\varepsilon]$$

$$\begin{bmatrix} \sigma_1 \\ \sigma_2 \\ \tau_{12} \end{bmatrix} = \begin{bmatrix} Q_{11} & Q_{12} & 0 \\ Q_{21} & Q_{22} & 0 \\ 0 & 0 & Q_{66} \end{bmatrix} \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \gamma_{12} \end{bmatrix} = [Q_{1-2}] \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \gamma_{12} \end{bmatrix}$$

Or

$$\begin{bmatrix}\sigma_1\\ \sigma_2\\ \sigma_{12}\end{bmatrix}=\begin{bmatrix}\frac{E_1}{1-\upsilon_{12}\upsilon_{21}} & \frac{\upsilon_{12}E_1}{1-\upsilon_{12}\upsilon_{21}} & 0\\ \frac{\upsilon_{21}E_1}{1-\upsilon_{12}\upsilon_{21}} & \frac{1}{1-\upsilon_{12}\upsilon_{21}} & 0\\ 0 & 0 & G_{12}\end{bmatrix}\begin{bmatrix}\varepsilon_1\\ \varepsilon_2\\ \gamma_{12}\end{bmatrix}$$

(2.16)

Where the subscribes 1, 2 and 3 refer to the properties along the fiber, transverse to the fiber and shear in plane, respectively. E_1 and E_2 are Young's moduli along and transverse to the fiber direction, respectively, υ_{12} is the Poisson's ratio and G_{12} is the shear modulus of the lamina under a loading along the fiber direction.

2.2.2. Transformation of Stress and Strain

Stress and strain at a point in a thin wall of composite tube are defined with respect to an arbitrary coordinate system, e.g. principle coordination. The values of the components of stress or strain change as this coordinate system is rotated. It is necessary to perform this rotation transformation between 2 general coordinate systems or to determine the magnitudes and orientation of the principal stress and strain components.

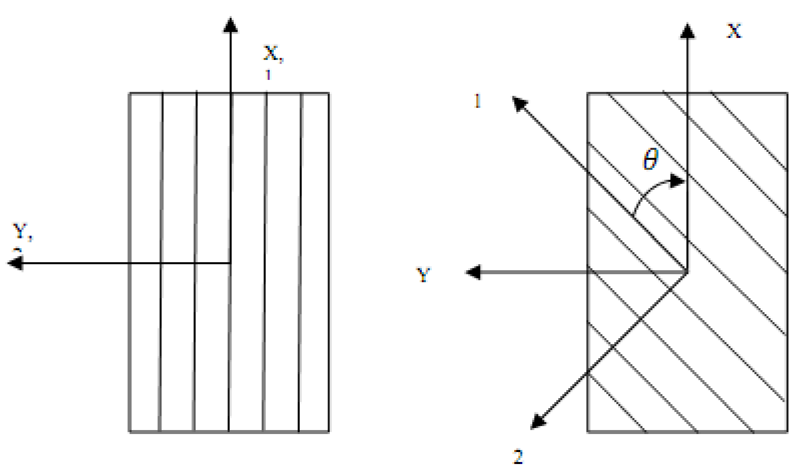


Figure 2.3 Coordinate of Lamina

Consider the fiber oriented with an angle, θ, with respect to lamina axis as shown in Figure 2.3. Then we can get a stress and strain transformation equation as

$$\begin{bmatrix} \sigma_1 \\ \sigma_2 \\ \tau_{12} \end{bmatrix} = [T_\sigma(\theta)]_z \begin{bmatrix} \sigma_x \\ \sigma_y \\ \tau_{xy} \end{bmatrix} \tag{2.17}$$

and

$$\begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \gamma_{12} \end{bmatrix} = [T_\varepsilon(\theta)]_z \begin{bmatrix} \varepsilon_x \\ \varepsilon_y \\ \gamma_{xy} \end{bmatrix} \tag{2.18}$$

When we transform the coordinate of plane stress from local to global coordinates, it can be written in the following matrix form

$$\begin{bmatrix} \sigma_x \\ \sigma_y \\ \tau_{xy} \end{bmatrix} = [T_\sigma\ (-\theta)]_z \begin{bmatrix} \sigma_1 \\ \sigma_2 \\ \tau_{12} \end{bmatrix} \tag{2.19}$$

Similarly, the strain transform becomes

$$\begin{bmatrix} \varepsilon_x \\ \varepsilon_y \\ \gamma_{xy} \end{bmatrix} = [T_\varepsilon(-\theta)]_z \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \gamma_{12} \end{bmatrix} \tag{2.20}$$

The stress transformation matrix, $[T_\sigma]_Z$, and strain transformation matrix, $[T_\varepsilon]_Z$, for a 2D case are given as

$$[T_\sigma(\theta)]_z = \begin{bmatrix} m_z^2 & n_z^2 & 2m_z n_z \\ n_z^2 & m_z^2 & -2m_z n_z \\ -m_z n_z & m_z n_z & m_z^2 - n_z^2 \end{bmatrix} \tag{2.21}$$

and

$$[T_\varepsilon(\theta)]_z = \begin{bmatrix} m_z^2 & n_z^2 & m_z n_z \\ n_z^2 & m_z^2 & -m_z n_z \\ -2m_z n_z & 2m_z n_z & m_z^2 - n_z^2 \end{bmatrix} \tag{2.22}$$

Where $m_z = \cos\theta$ and $n_z = \sin\theta$ the angle θ is positive when the angle from the x-y axis to 1-2 axis is counter clockwise. From equation (2.21) and (2.22), we have:

$$[T_\varepsilon(\theta)]_z = [T_\sigma(-\theta)]_z^T \tag{2.23}$$

Substitute equation 2.21 into 2.19 we have stress – strain in relationship as

$$\begin{bmatrix}\sigma_x\\ \sigma_y\\ \tau_{xy}\end{bmatrix} = [T_\sigma(-\theta)]_z \begin{bmatrix}Q_{11} & Q_{12} & 0\\ Q_{21} & Q_{22} & 0\\ 0 & 0 & Q_{66}\end{bmatrix} [T_\sigma(-\theta)]_z^T \begin{bmatrix}\varepsilon_x\\ \varepsilon_y\\ \gamma_{xy}\end{bmatrix}$$

Or,

$$\begin{bmatrix}\sigma_x\\ \sigma_y\\ \tau_{xy}\end{bmatrix} = \begin{bmatrix}\bar{Q}_{11} & \bar{Q}_{12} & \bar{Q}_{16}\\ \bar{Q}_{21} & \bar{Q}_{22} & \bar{Q}_{26}\\ \bar{Q}_{61} & \bar{Q}_{62} & \bar{Q}_{66}\end{bmatrix} \begin{bmatrix}\varepsilon_x\\ \varepsilon_y\\ \gamma_{xy}\end{bmatrix} \tag{2.24}$$

Where,

$$\bar{Q}_{11} = m_z^4 Q_{11} + 2n_z^2 m_z^2 (Q_{12} + 2Q_{66}) + n_z^4 Q_{22} \tag{2.25}$$

$$\bar{Q}_{12} = 2n_z^2 m_z^2 (Q_{11} + Q_{22} - 4Q_{66}) + (m_z^4 + n_z^4) Q_{12} \tag{2.26}$$

$$\bar{Q}_{22} = n_z^4 Q_{11} + 2n_z^2 m_z^2 (Q_{12} + 2Q_{66}) + m_z^3 n_z (Q_{22} - Q_{22} + 2Q_{66}) \tag{2.27}$$

$$\bar{Q}_{16} = n_z^3 m_z (Q_{11} - Q_{12} - 2Q_{66}) + m_z n_z^3 (Q_{12} - Q_{22} + 2Q_{66}) \tag{2.28}$$

$$\bar{Q}_{26} = n_z^3 m_z (Q_{11} - Q_{12} - 2Q_{66}) + n_z m_z^3 (Q_{12} - Q_{22} + 2Q_{66}) \tag{2.28}$$

$$\bar{Q}_{66} = n_z^2 m_z^2 (Q_{11} + Q_{22} - 2Q_{12} - 2Q_{66}) + (m_z^4 + n_z^4) Q_{66} \tag{2.29}$$

2.3 Laminate Constitutive Equation

2.3.1 Definitions of Strains and Displacements

A displacement of the plate in the x, y, and z direction is designated as u, v, and w. The strains are defined as;

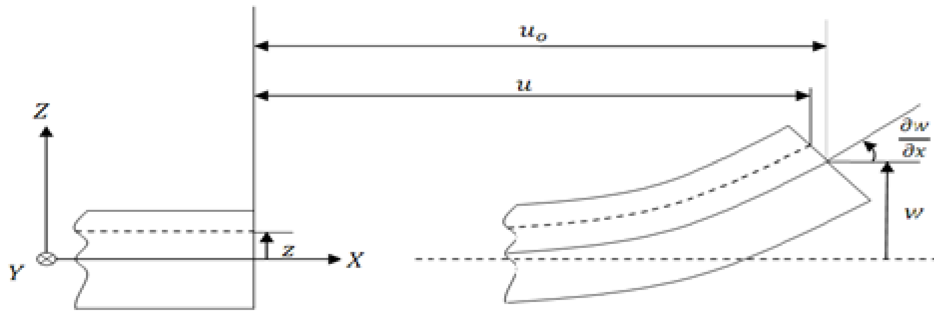


Figure 2.4 Laminate Section Before and After Deformation

$$\varepsilon_x \equiv \frac{\partial u}{\partial x}\ ;\ \varepsilon_y \equiv \frac{\partial v}{\partial y}\ ;\ \gamma_{xy} \equiv \left(\frac{\partial u}{\partial y} + \frac{\partial v}{\partial x}\right) \qquad (2.31)$$

The total in-plane displacement at any point in the plate with coordinated Z can be written as

$$u \equiv u_0 - z\frac{\partial w}{\partial x}\ ;\ v = v_0 - z\frac{\partial w}{\partial y}\ ;\ w = w_0 \qquad (2.32)$$

From equation (2.31) and (2.32):

$$\varepsilon_x = \frac{\partial u}{\partial x} = \frac{\partial u_0}{\partial x} - z\frac{\partial^2 w_0}{\partial x^2}$$

$$\varepsilon_y = \frac{\partial v}{\partial x} = \frac{\partial v_0}{\partial x} - z\frac{\partial^2 w_0}{\partial y^2}$$

$$\gamma_{xy} = \frac{\partial u}{\partial x} + \frac{\partial v}{\partial x} = \frac{\partial u_0}{\partial x} + \frac{\partial v_0}{\partial x} - 2z\frac{\partial^2 w_0}{\partial x\,\partial y}$$

(2.33)

Defining:

$$\frac{\partial u_0}{\partial x} = \varepsilon_x^0\ ;\ \frac{\partial v_0}{\partial x} = \varepsilon_y^0\ ;\ \frac{\partial u_0}{\partial x} + \frac{\partial v_0}{\partial x} = \gamma_{xy}^0$$

and

$$-\frac{\partial^2 w_0}{\partial x^2} = K_x\ ;\ -\frac{\partial^2 w_0}{\partial y^2} = K_y\ ;\ -2\frac{\partial^2 w_0}{\partial x\,\partial y} = K_{xy} \qquad (2.34)$$

To be the plate curvatures will make notation easier. Equation 2.33 can now be written in matrix from as:

$$\begin{bmatrix} \varepsilon_x \\ \varepsilon_y \\ \gamma_{xy} \end{bmatrix} = \begin{bmatrix} \varepsilon_x^0 \\ \varepsilon_y^0 \\ \gamma_{xy}^0 \end{bmatrix} + z \begin{bmatrix} K_x \\ K_y \\ K_{xy} \end{bmatrix} \tag{2.35}$$

The plate curvature K_x or K_y is rate of change of slope of the bending plate in either the x- or y-direction, respectively. The plate curvature term K_y is the amount of bending in the x direction along the y-axis. Finally, the stress in each K^{th} ply at a distance of z_k from the reference plane in terms of strains and laminate curvatures can be written as:

$$\begin{bmatrix} \sigma_x \\ \sigma_y \\ \tau_{xy} \end{bmatrix}_K = \begin{bmatrix} Q_{11} & Q_{12} & Q_{16} \\ Q_{21} & Q_{22} & Q_{26} \\ Q_{61} & Q_{62} & Q_{66} \end{bmatrix}_K \left\{ \begin{bmatrix} \varepsilon_x^0 \\ \varepsilon_y^0 \\ \gamma_{xy}^0 \end{bmatrix} + z_K \begin{bmatrix} K_x \\ K_y \\ K_{xy} \end{bmatrix} \right\} \tag{2.36}$$

2.3.2 Constitutive Equation of Laminated Plate

The stress in each ply varies linearly through the thickness of the laminate this due to the different material properties of the layer resulting from different fiber orientation. Since there exist a discontinuous variation of stresses from a layer to layer in the laminate, it will be convenient to define stress in term of equivalent forces acting at the middle surface. The three stress resultants are therefore:

$$N_x \equiv \sum_{i=1}^{n} \int_{h_{k-1}}^{h_k} \sigma_x^k \cdot dz$$

$$N_y \equiv \sum_{i=1}^{n} \int_{h_{k-1}}^{h_k} \sigma_y^k \cdot dz \tag{2.37}$$

$$N_{xy} \equiv \sum_{i=1}^{n} \int_{h_{k-1}}^{h_k} \tau_{xy}^k \cdot dz$$

Following the same procedure, the moment resultants can be defined as:

$$M_x \equiv \sum_{i=1}^{n} \int_{h_{k-1}}^{h_k} \sigma_x^k \cdot zdz$$

$$M_y \equiv \sum_{i=1}^{n} \int_{h_{k-1}}^{h_k} \sigma_y^k \cdot zdz \tag{2.38}$$

$$M_{xy} \equiv \sum_{i=1}^{n} \int_{h_{k-1}}^{h_k} \tau_{xy}^k \cdot zdz$$

Where N_x, N_y, N_{xy} are the forces per unit width of the beam M_x, M_y, M_{xy} are the moment per unit width of the beam. Substituting Equation (2.36) in Equation (2.37) and (2.38) the total constitutive equation or load-deformation relations for the laminate can now written as:

$$\begin{pmatrix} N \\ M \end{pmatrix} = \begin{pmatrix} A & B \\ B & D \end{pmatrix} \begin{pmatrix} \varepsilon^0 \\ k \end{pmatrix} \tag{2.39}$$

Where;

$$[A] = \sum_{k=1}^{n} [\overline{Q}](h_k - h_{k-1}) \tag{2.40}$$

$$[B] = \frac{1}{2} \sum_{k=1}^{n} [\overline{Q}](h^2_k - h^2_{k-1}) \tag{2.41}$$

$$[D] = \frac{1}{3} \sum_{k=1}^{n} [\overline{Q}](h^3_k - h^3_{k-1}) \tag{2.42}$$

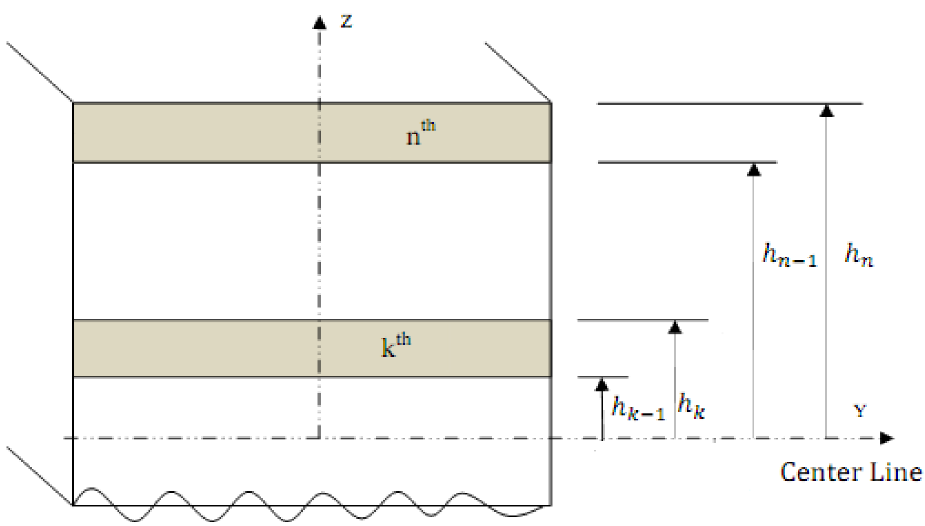


Figure 2.5 Coordinate Notations of individual Plies

h_k and h_{k-1} are the coordinates of the upper and lower surface of the k^{th} lamina as shown in Figure 2.5

A matrix is called extensional stiffness matrix, B matrix is called the coupling stiffness matrix and D matrix is called the bending stiffness. For a symmetrical laminate, it can be proved that B matrix is a zero matrix however an unsymmetrical laminate B matrix is non-zero because of the coupling stiffness between in-plane and out-of plane are exist.

The inverse of load-deformation relations is used to work easily with strains and curvature of the laminates for any applied load. Laminate compliance matrix can be expressed as:

$$\begin{bmatrix} \varepsilon^0 \\ k \end{bmatrix} = \begin{bmatrix} a & b \\ b^T & d \end{bmatrix} \begin{bmatrix} N \\ M \end{bmatrix} \tag{2.43}$$

Where

$$\begin{bmatrix} a & b \\ b^T & d \end{bmatrix} = \begin{bmatrix} A & B \\ B & D \end{bmatrix}^{-1} \tag{2.44}$$

For the given [N] and [M], the mid-plane strains, $[\varepsilon^0]$ and the curvature, [K] can be solved from equation (2.43). By using Equation (2.36), the stresses of each ply can be obtained.

2.3.3 Application of Laminated Plate Theory to Thin-Walled Composite tube

For a thin-walled tube under torsion, a shear stress is induced, Because of stress variation from layer to layer. It is convenient to define equivalent shear force acting on the mid-plane of laminate along cross-section of the tube. Since the shear flow is constant along the contour of the tube, we can consider a laminate of the tube subjected to a shear load.

Since the analysis is computed under torsion load only. All of forces and moments in x and y direction are negligible.

$$N_x = N_y = 0$$

$$M_x = M_y = M_{xy} = 0$$

The total constitutive equation or load-deformation relations for the laminate can now write as:

$$\begin{Bmatrix} \varepsilon_x^0 \\ \varepsilon_y^0 \\ \gamma_{xy}^0 \\ K_x \\ K_y \\ K_{xy} \end{Bmatrix} = \begin{bmatrix} a & b \\ b^T & d \end{bmatrix}_{6x6} \begin{Bmatrix} 0 \\ 0 \\ N_{xy} \\ 0 \\ 0 \\ 0 \end{Bmatrix} \tag{2.45}$$

Where

$$N_{xy} = q = \frac{T}{2\pi AB} \tag{2.46}$$

From Equation 2.45, the stress of each k_{th} layer in laminate can be calculated from

$$\begin{bmatrix} \sigma_x \\ \sigma_y \\ \gamma_{xy} \end{bmatrix}_{kth} = \begin{bmatrix} \overline{Q}_{11} & \overline{Q}_{12} & \overline{Q}_{16} \\ \overline{Q}_{21} & \overline{Q}_{22} & \overline{Q}_{26} \\ \overline{Q}_{61} & \overline{Q}_{62} & \overline{Q}_{66} \end{bmatrix}_{kth} \left(\begin{bmatrix} \varepsilon_x^0 \\ \varepsilon_y^0 \\ \gamma_{xy}^0 \end{bmatrix}_{kth} + Z_{kth} \begin{bmatrix} K_x \\ K_y \\ K_{xy} \end{bmatrix} \right) \tag{2.36}$$

CHAPTER 3

FINITE ELEMENT MODEL OF LAMINATED TUBULAR STRUCTURE

The finite element analysis is a computer assisted numerical technique useful in solving for the response of a structure subjected to loading. The model is divided into small blocks called elements. These elements are connected by nodes at which the finite element boundary conditions are applied. A set of algebraic equations are created for each element and combined simultaneous equations are solved. A post processor to the finite element program may be helpful in displaying the stresses and deflections in the form of contours for easy comprehension. A number of finite element packages are available for the analysis of complex structures under various types of loads. A finite element package is chosen depending on the complexity of the model and the results needed.

ANSYS 11.0 is a commercial package that had been used to develop the required 3D finite element model in this study. ANSYS is a versatile finite element package which can be used to analyze structural, thermal, electrical, and contact problems. The preprocessor step consists of selecting the proper elements, providing real constants, material properties, and meshing the model; loads and displacement boundary conditions can also be applied in this module. In this Study the finite element model was developed to conduct the effect of stress and shear stress along the contour of laminated tube with circular cross-section. The detail of preprocessor step will be explained in the later section.

3.1 Geometry and Material properties of Composite Tubular Structure

3.1.1. Geometry of the Tube

The considerable laminated tube in this research has wall thickness, t, is 0.005 in. that consider as a constant along the cross-section. The major radius,a, is 0.5 in and minor radius,b, are varies from 0.5 to 0.1 in. The length of the composite tube, L, is 5 in. The geometry of composite tube is depicted in figure 3.1.

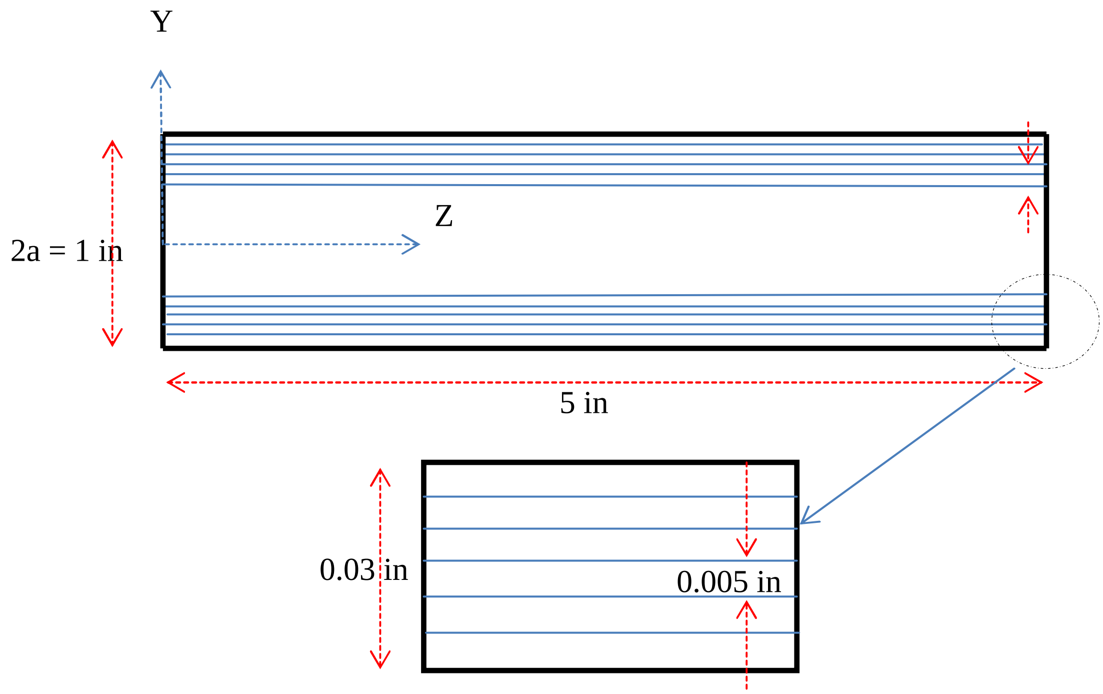


Figure 3.1 2D Dimension of Composite Tubular Structure

The layup of the laminate were conducted in three different categories, symmetrical and balance, anti-symmetrical and balance and symmetrical and unbalance. The staking sequence of symmetrical and balance laminate is $[\pm45/0]_s$. The staking sequence of anti-symmetrical and balance laminate is $[45/-45/0_2/45/-45]$. The staking sequence of anti-symmetrical and unbalance is $[45/0/90]_s$. All of the laminate consists of 6 layers, with ply thickness 0.005in each.

3.1.2. Material properties

The unidirectional graphite/epoxy AS4/3501-6 is chosen as the composite material used in this research. The unidirectional layer orthotropic material properties are given as follows,

$E_1 = 21.3 \times 10^6$ psi , $E_2 = 1.5 \times 10^6$ psi, $E_3 = 1.5 \times 10^6$ psi,

G_{12} = 1.0 x 10^6 psi , G_{23} =0.54 x 10^6 psi, G_{13}= 1.0 x 10^6 psi,

v_{12} = 0.27 x 10^6, v_{23} =0.54 x 10^6, v_{13}= 0.27 x 10^6

E, G, and v are referring to young's modulus, shear modulus, and Poisson's ratio of the composite material, respectively. The subscripts 1, 2, and 3 are along fiber direction, transverse and perpendicular to the plane, respectively.

3.2 Development of Finite Element Model

3.2.1 Element type used

ANSYS V11 has various shell element like Shell 91Shell 99 is an 8 node, 3D shell element with six degrees of freedom at each node. It is designed for modeling thin to moderately thick plate and shell structure with a side to thickness ratio of roughly 10 or greater. The Shell 99 element allows a total of 100 uniform thickness layers. However, If more than 100 layers are required, we can input ours own material properties matrix.

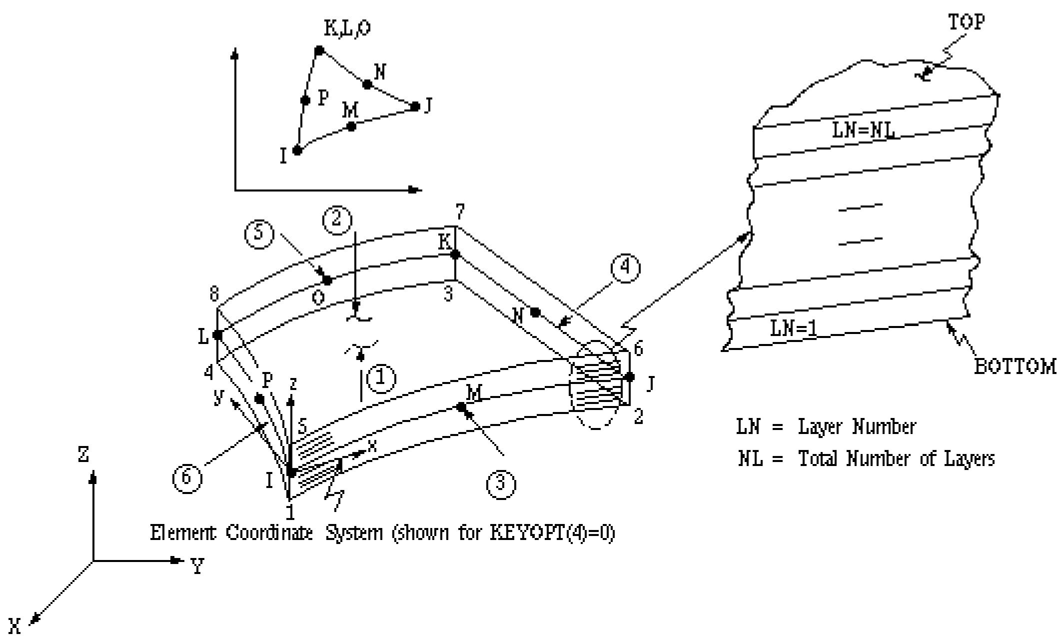


Figure 3.2 SHELL99 Geometry

3.2.2 Modeling

In the present analysis, Shell99 is used to model the composite circular tube. The element has six degrees of freedom at each node which is translations in the nodal x, y, and z directions and rotations about the nodal x, y, and z-axes. Material properties are set as describe in section 3.2.1.The model start from creating a key points on X-Y plane. The 80 key points were created using K command. The key-points were linked together using BSPLIN command. All the key-points became a set of line that composes of 80 short lines. Those lines need to be glue together as one line using LGLUE command. The line was extruded along the Z direction for 5 inches long. A volume that composes of sub areas were created after extruded processer. The volume was deleted by VDELE command and left over 82 sub areas. The both end areas of the tube were deleted by ADELE command. All of the areas were glue together using AGLUE command. The complete composite circular tube modeling is done as figure below.

3.2.3 Meshing

Meshing can be done in two ways, free and map meshing. In free meshing, the elements that are created are of no definite shape and pattern. In contrast to this, a mapped mesh produces a definite element shape and follows a particular pattern.

A map meshing is chosen to apply on the composite circular tube model. It is important to divide the areas properly for a good map mashing. Therefore all of the lines along Z direction and along the tubular cross section were divided into 160 and 80 tiny segments respectively before map meshing will be applied. Many tiny square areas are generated around the composite tube which is called an element. The 12,800 elements were generated after applying map meshing into composite circular tube model.

3.2.4 Boundary conditions

Boundary Conditions are the constraints and loads that can simulate the effect of the environment surrounding a body. Loads are applied in the form of forces, moments, pressures, and temperatures. The displacement constraints are applied by restricting the degrees of freedom at the corresponding nodes of a model. There are three boundary conditions are enforced. First, all nodes at one face of the end of the circular tube is constrained along the X Y and Z direction (UX = UY = UZ = 0). Second, all of the nodes at the same face is constrained on rotation in X, Y and Z direction (ROTX = ROTY = ROTZ = 0). Last, toque was applied in another free end by using constraint equations features that provided in ANSYS 11.0.

3.2.5 Loading condition

Constraint equations provide many useful features in ANSYS, such as tying together dissimilar meshes, representing parts of the system not explicitly modeled, or distributing loads. Two automated methods of generating constraint equations are the CERIG and RBE3 commands. Constraint equations in ANSYS are linear, so they are not valid for large-rotation analyses.

RBE3 is the most common method applied, because it will work for all cases. It uses link elements with appropriately high stiffness. Using RBE3, a rigid region is not formed, but the applied loads are distributed. Because no rigidity is formed, no rotational moments of inertia are transferred to the slave nodes and the key option for Mass21 must be set to ignore rotational inertia effects.

CERIG is the automatic CE generator, the user selects one master node, several slave nodes, and the DOF affected. The master node in this case means that this is the node which controls the behavior of the rigid region. The Mass21 key option must be set such that it expects both a mass and a rotational inertia even if the rotational inertia is zero.

MPC184 is a rigid link/beam element for use in large rotation problem. These elements can be used to represent rigid connections, even in nonlinear applications. It requires no real constants, no suppression in any DOF, and also has optional material properties of ALPX and DENS for thermal expansion and density, respectively.

3.3 Validation of Finite Element Model and Results

The finite element model developed in this research is validated using isotropic material. Shear stress along the cross section contour of the constant thickness thin wall tube is concerned as the validated variable. The size of the model, meshing, elements, boundary conditions, and loading conditions will remain the same as using in composite case. The isotropic material properties are given as follows,

$$E_1 = E_2 = E_3 = 10 \text{ x } 10^6 \text{ psi}$$

$$G_{12} = G_{23} = G_{13} = 3.75 \text{ x } 10^6 \text{ psi}$$

$$v_{12} = v_{23} = v_{13} = \frac{\text{E11}}{2(1+v_{12})}$$

The result is shown in the Graph and table below

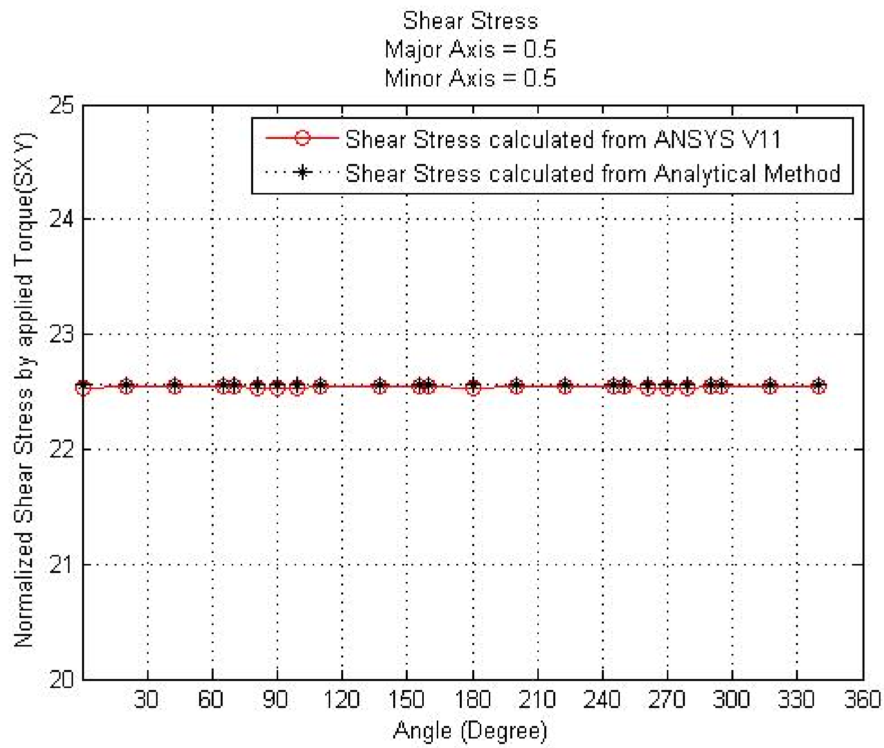


Figure 3.3 Comparison of τ_{xy} in isotropic tube under torsion with $\frac{\mathrm{b}}{\mathrm{a}} = 1$

Table 3.1 Comparison of τ_{xy} in isotropic tube under torsion with $\frac{\mathrm{b}}{\mathrm{a}} = 1$

ANGLE (deg)	SXY FEM Result (lb-in^2)	SXY Analytical Result (lb-in^2)	% Error
0	22.533	22.5581	0.111268
20.25	22.549	22.5581	0.040340
42.75	22.549	22.5581	0.040340
65.25	22.549	22.5581	0.040340
69.75	22.549	22.5581	0.040340
81	22.533	22.5581	0.111268
90	22.533	22.5581	0.111268
99	22.533	22.5581	0.111268
110.25	22.549	22.5581	0.040340
137.25	22.549	22.5581	0.040340
155.75	22.549	22.5581	0.040340
159.75	22.549	22.5581	0.040340
180	22.533	22.5581	0.111268
200.25	22.549	22.5581	0.040340

Table 3.1 – *Continued*

222.75	22.549	22.5581	0.040340
245.25	22.549	22.5581	0.040340
249.75	22.549	22.5581	0.040340
261	22.533	22.5581	0.111268
270	22.533	22.5581	0.111268
279	22.533	22.5581	0.111268
290.25	22.549	22.5581	0.040340
294.75	22.549	22.5581	0.040340
317.25	22.549	22.5581	0.040340
339.75	22.549	22.5581	0.040340

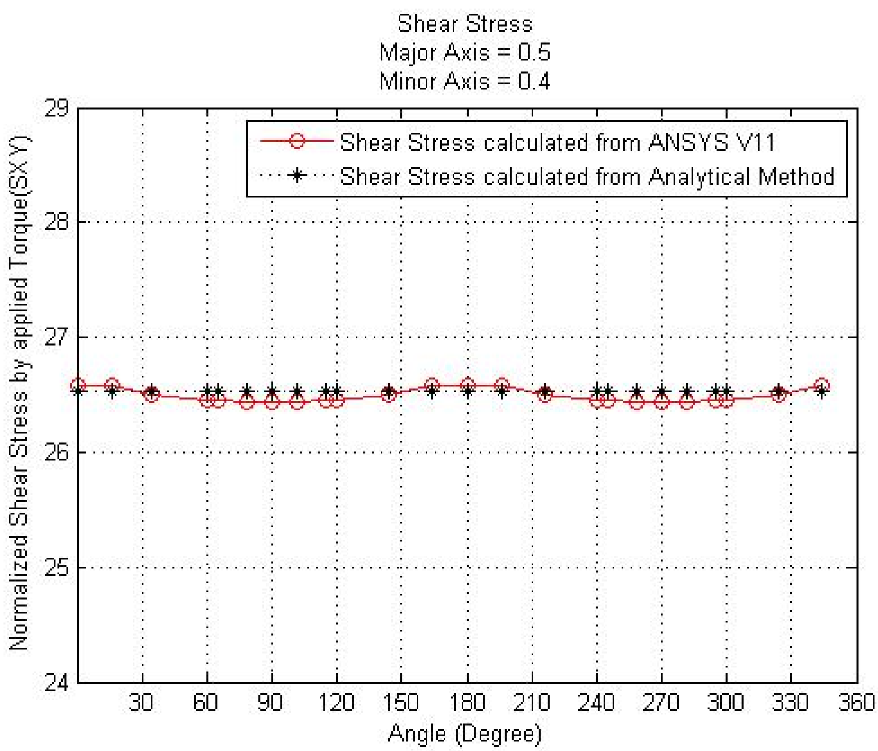


Figure 3.4 Comparison of τ_{xy} in isotropic tube under torsion with $\frac{\mathrm{b}}{\mathrm{a}} = 0.8$

Table 3.2 Comparison of τ_{xy} in isotropic tube under torsion with $\frac{\mathrm{b}}{\mathrm{a}} = 0.8$

ANGLE (deg)	**SXY FEM Result (lb-in^2)**	**SXY Analytical Result (lb-in^2)**	**% Error**
0	26.583	26.5266	0.212617
16.432	26.574	26.5266	0.178689

Table 3.2 – *Continued*

34.46	26.496	26.5266	0.115356
60.03	26.46	26.5266	0.251069
65.23	26.457	26.5266	0.262378
78.8	26.442	26.5266	0.318925
90	26.441	26.5266	0.322695
101.2	26.442	26.5266	0.318925
114.77	26.457	26.5266	0.262378
119.97	26.46	26.5266	0.251069
143.54	26.574	26.5266	0.178689
163.57	26.496	26.5266	0.115356
180	26.583	26.5266	0.212617
196.432	26.574	26.5266	0.178689
216.46	26.496	26.5266	0.115356
240.03	26.46	26.5266	0.251069
245.23	26.457	26.5266	0.262378
258.8	26.442	26.5266	0.318925
270	26.441	26.5266	0.322695
281.2	26.442	26.5266	0.318925
294.77	26.457	26.5266	0.262378
299.97	26.46	26.5266	0.251069
323.54	26.496	26.5266	0.115356
343.57	26.574	26.5266	0.178689

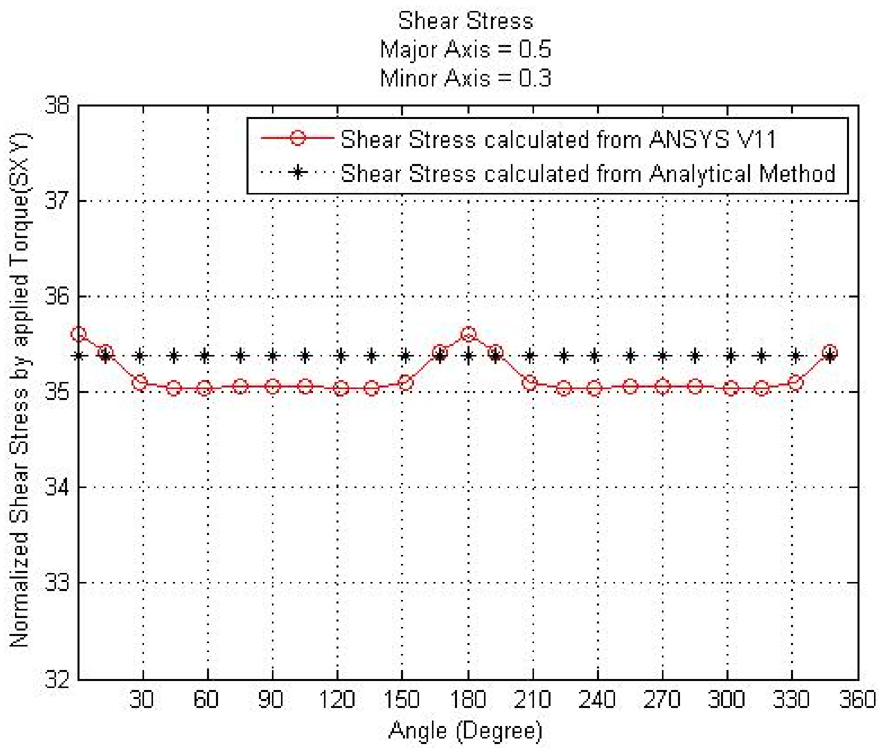


Figure 3.5 Comparison of τ_{xy} in isotropic tube under torsion with $\frac{\mathrm{b}}{\mathrm{a}} = 0.6$

Table 3.3 Comparison of τ_{xy} in isotropic tube under torsion with $\frac{\mathrm{b}}{\mathrm{a}} = 0.6$

ANGLE (deg)	**SXY FEM Result (lb-in^2)**	**SXY Analytical Result (lb-in^2)**	**% Error**
0	35.603	35.368	0.664442
12.46	35.423	35.368	0.155508
28.98	35.098	35.368	0.763402
44.16	35.038	35.368	0.933047
58.38	35.043	35.368	0.918910
75.21	35.048	35.368	0.904773
90	35.053	35.368	0.890636
104.79	35.048	35.368	0.904773
121.62	35.043	35.368	0.918910
135.84	35.038	35.368	0.933047
151.02	35.423	35.368	0.155508
167.54	35.098	35.368	0.763402
180	35.603	35.368	0.664442
192.46	35.423	35.368	0.155508

Table 3.3 – *Continued*

208.98	35.098	35.368	0.763402
224.16	35.038	35.368	0.933047
238.38	35.043	35.368	0.918910
255.21	35.048	35.368	0.904773
270	35.053	35.368	0.890636
284.79	35.048	35.368	0.904773
301.62	35.043	35.368	0.918910
315.84	35.038	35.368	0.933047
331.02	35.098	35.368	0.763402
347.54	35.423	35.368	0.155508

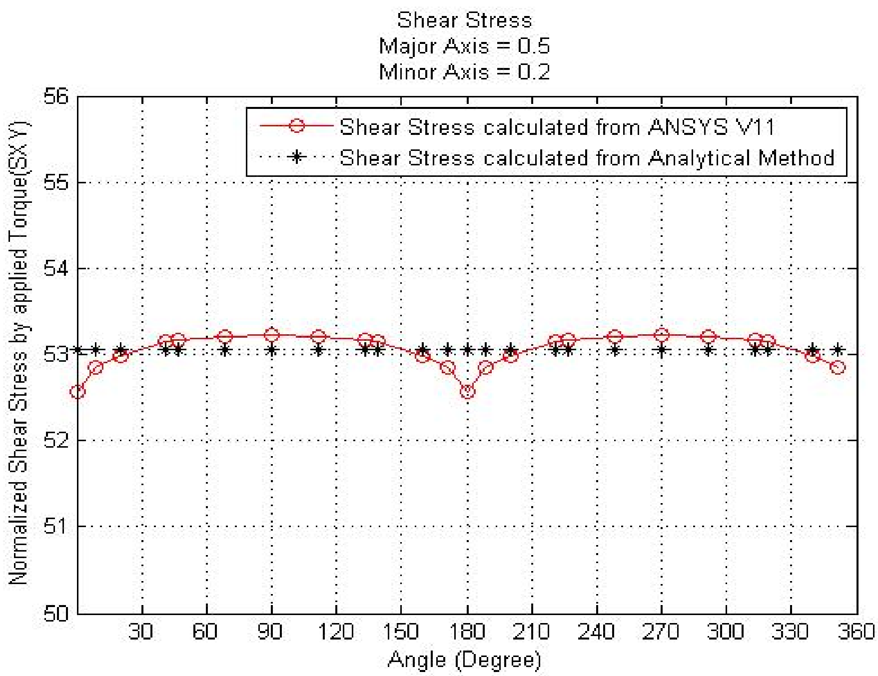


Figure 3.6 Comparison of τ_{xy} in isotropic tube under torsion with $\frac{b}{a} = 0.4$

Table 3.4 Comparison of τ_{xy} in isotropic tube under torsion with $\frac{b}{a} = 0.4$

ANGLE (deg)	**SXY FEM Result (lb-in^2)**	**SXY Analytical Result (lb-in^2)**	**% Error**
0	52.559	53.052	0.929277
8.35	52.847	53.052	0.386413
20.25	52.977	53.052	0.141371
40.9	53.147	53.052	0.179070

Table 3.4 – *Continued*

47.27	53.174	53.052	0.229963
68.4	53.216	53.052	0.309131
90	53.228	53.052	0.331750
111.6	53.216	53.052	0.309131
132.73	53.174	53.052	0.229963
139.1	53.147	53.052	0.179070
159.75	52.847	53.052	0.386413
171.65	52.977	53.052	0.141371
180	52.559	53.052	0.929277
188.35	52.847	53.052	0.386413
200.25	52.977	53.052	0.141371
220.9	53.147	53.052	0.179070
227.27	53.174	53.052	0.229963
248.4	53.216	53.052	0.309131
270	53.228	53.052	0.331750
291.6	53.216	53.052	0.309131
312.73	53.174	53.052	0.229963
319.1	53.147	53.052	0.179070
339.75	52.977	53.052	0.141371
351.65	52.847	53.052	0.386413

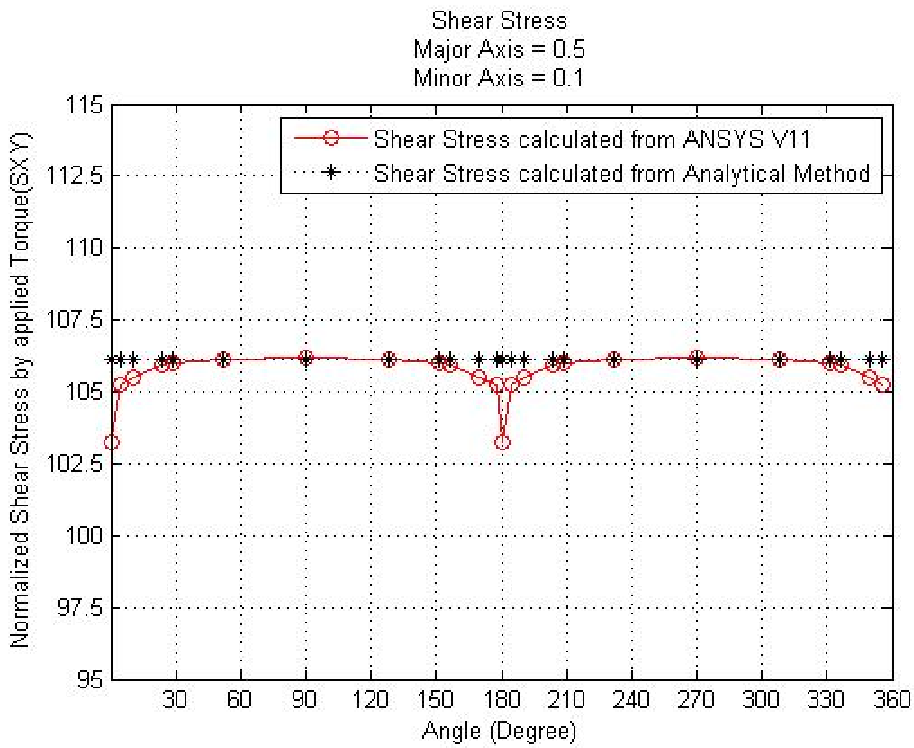


Figure 3.7 Comparison of τ_{xy} in isotropic tube under torsion with $\frac{b}{a} = 0.2$

Table 3.5 Comparison of τ_{xy} in isotropic tube under torsion with $\frac{b}{a} = 0.2$

ANGLE (deg)	SXY FEM Result (lb-in^2)	SXY Analytical Result (lb-in^2)	% Error
0	103.24	106.103	2.698321
4.18	105.26	106.103	0.794511
10.44	105.52	106.103	0.549466
23.41	105.94	106.103	0.153624
28.42	106.01	106.103	0.087651
51.62	106.14	106.103	0.034872
90	106.17	106.103	0.063146
128.38	106.14	106.103	0.034872
151.58	106.01	106.103	0.087651
156.59	105.94	106.103	0.153624
169.56	105.26	106.103	0.794511
177.59	105.52	106.103	0.549466
180	103.24	106.103	2.698321
184.18	105.26	106.103	0.794511

Table 3.5 – *Continued*

190.44	105.52	106.103	0.549466
203.41	105.94	106.103	0.153624
208.42	106.01	106.103	0.087651
231.62	106.14	106.103	0.034872
270	106.17	106.103	0.063146
308.38	106.14	106.103	0.034872
331.58	106.01	106.103	0.087651
336.59	105.94	106.103	0.153624
349.56	105.52	106.103	0.549466
355.82	105.26	106.103	0.794511

From the all graphs and tables above, we found that the accuracy of shear stress is affected from radius ratio, as large as radius ratio is as much as errors appear. The highest shear stress error is 0.04 % in the case of minor radius is 0.5in but the biggest error became 2.7% when the minor radius is 0.1in which is about 80% smaller than the major radius, which is 0.5in. All of the error is an impact from surface distortion and curvature that usually has an effect on tubular structure with large aspect ratio.

CHAPTER 4

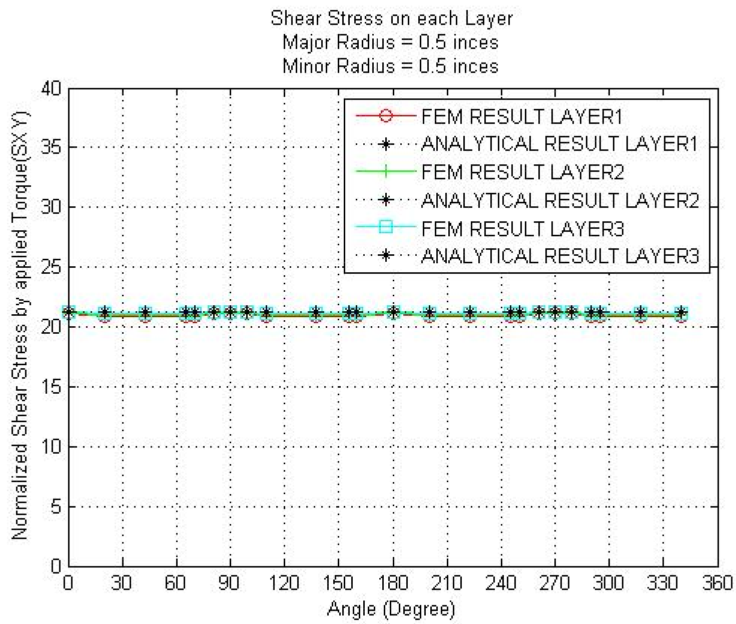
RESULT

There are two parts which are going to be presented. First, the different results of tubular structure with symmetric layups between finite element method,(FEM) and classical laminated plate theory,(CLPT) are compared. The stacking sequence of $[0]_{6T}$, $[45]_{6T}$, and $[+45/-45/0]_S$ are investigated. The other part exhibits the different results of tubular structure with unsymmetrical layups between finite element method and laminated plate theory which the stacking sequence are [+45/-45/0/0/45/-45] and [+45/-45/0/+45/-45/0].

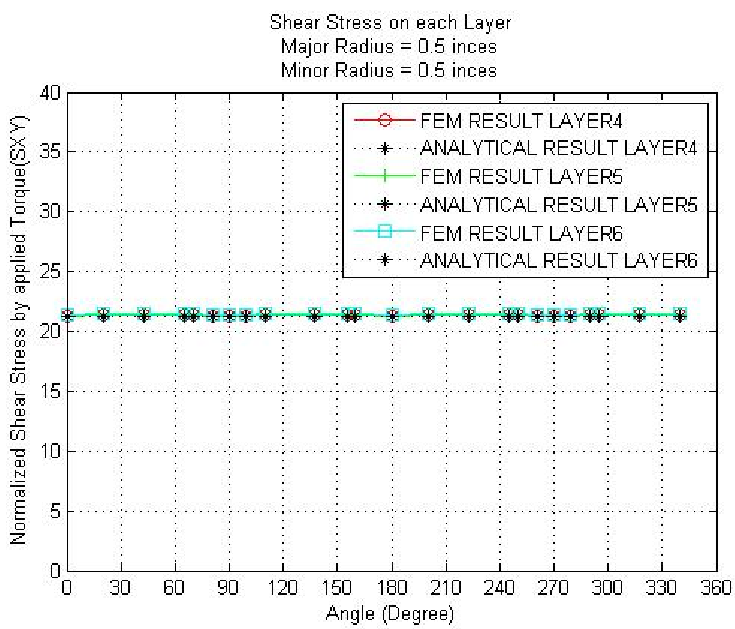
4.1 The comparison results of Symmetric layups between FEM and CLPT

4.1.1 Symmetric Single fiber orientation $[0]_{6T}$ *and* $[45]_{6T}$

The $[0]_{6T}$ and $[45]_{6T}$ are no z-displacement in the model. This is because the model is now symmetrically layered, and the material orientation does not cause a curvature effect due to varying moduli on either side of the composite centerline. This can also be seen in the composite constitutive matrices by the null extensional-bending stiffness or B matrix. From the graphs above, we saw the shear stress results that got from FEM are generally agree to the CLPT. The miss match are exist In the high specific curvature region when the radius ratio is high, $\frac{b}{a} = 0.4$ and, $\frac{b}{a} = 0.2$ and the result are present as a graphs below

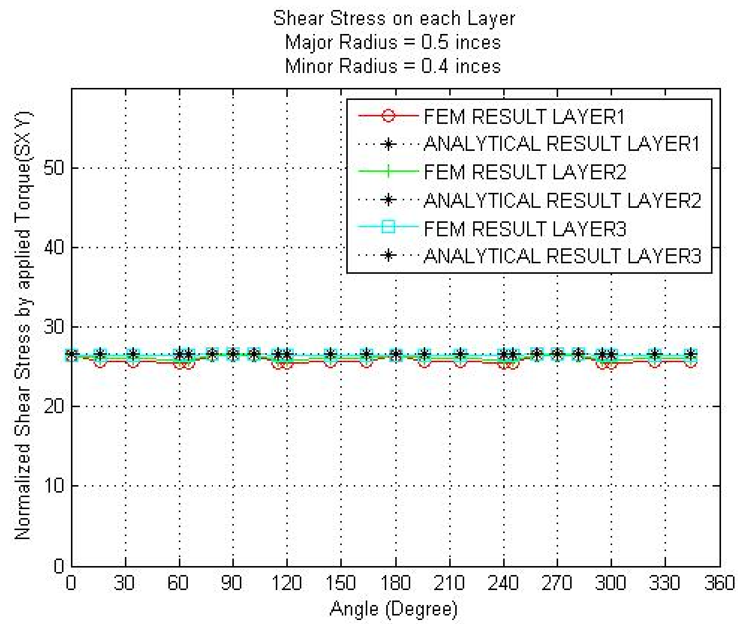


(a)

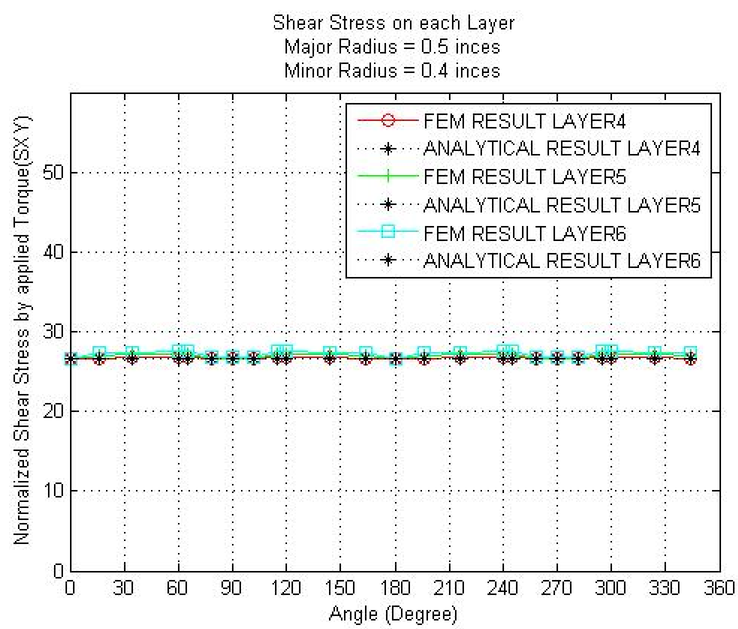


(b)

Figure 4.1 The comparison between FEM and CLPT for $[0]_{6T}$ from layer (a) 1 - 3 and (b) 3 - 6 with $\frac{b}{a} = 1$

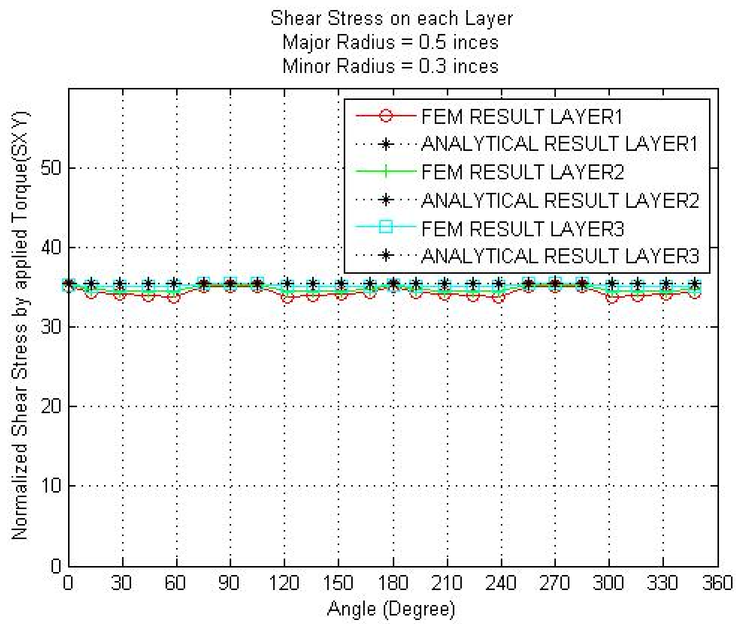


(a)

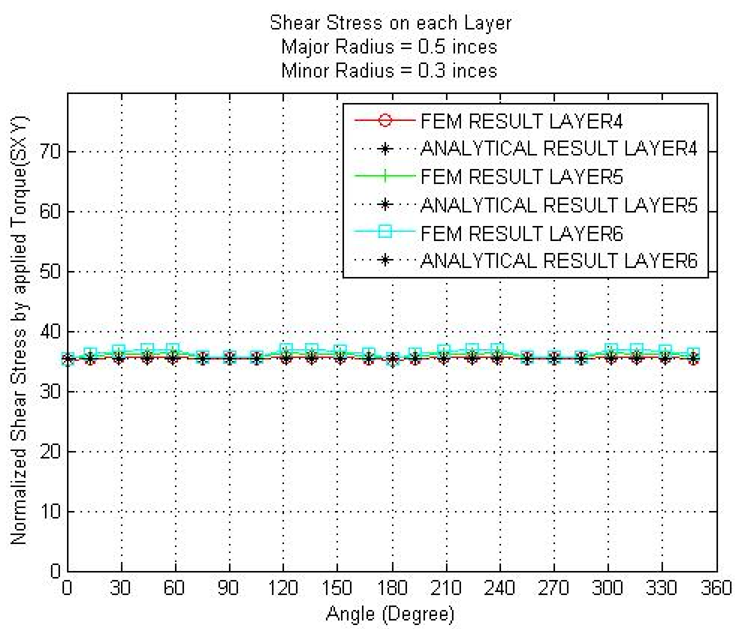


(b)

Figure 4.2 The comparison between FEM and CLPT for $[0]_{6T}$ from layer (a) 1 - 3 and (b) 3 - 6 with $\frac{b}{a} = 0.8$

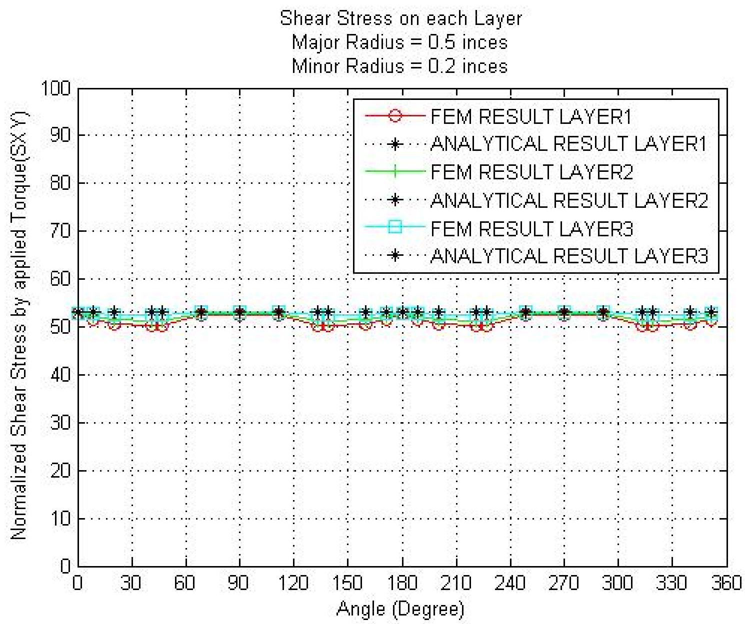


(a)

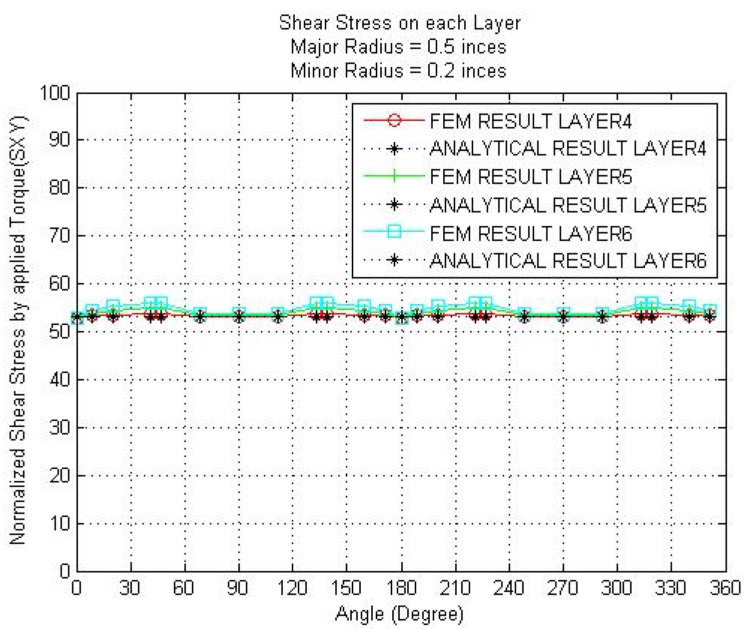


(b)

Figure 4.3 The comparison between FEM and CLPT for $[0]_{6T}$ from layer (a) 1 - 3 and (b) 3 - 6 with $\frac{b}{a} = 0.6$

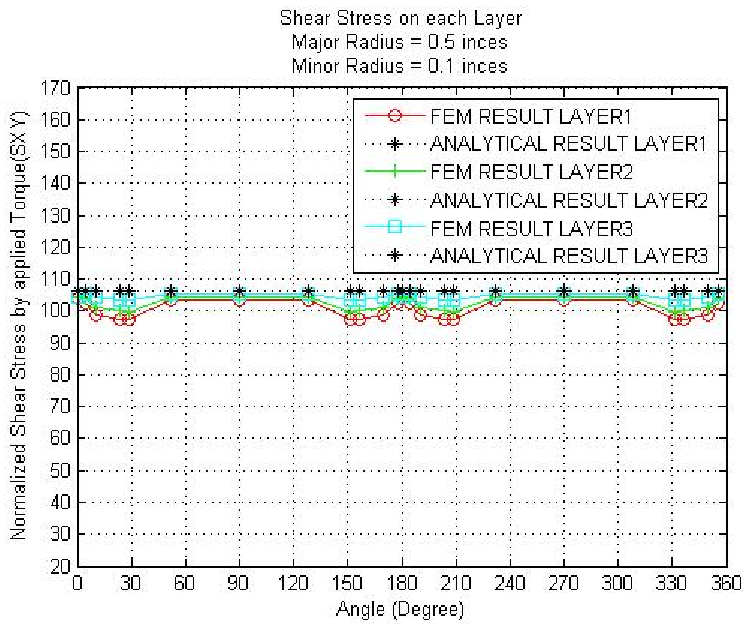


(a)

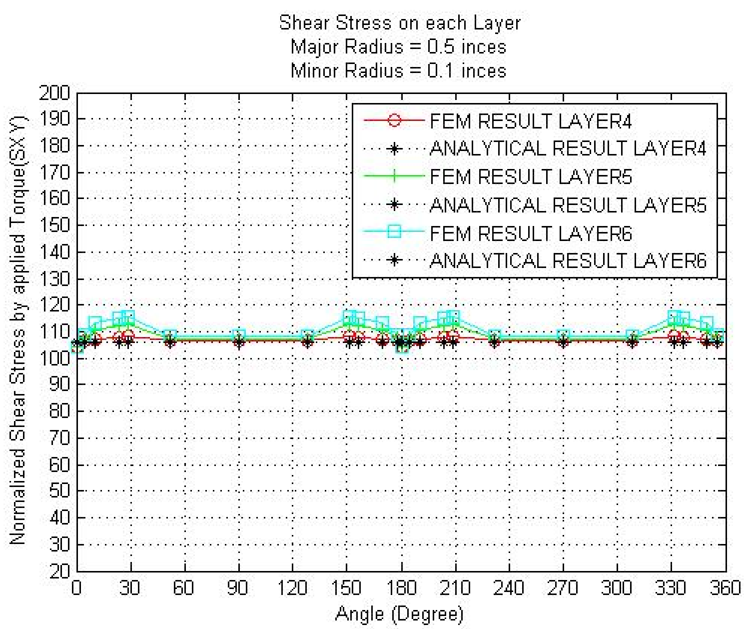


(b)

Figure 4.4 The comparison between FEM and CLPT for $[0]_{6T}$ from layer (a) 1 - 3 and (b) 3 - 6 with $\frac{b}{a} = 0.4$

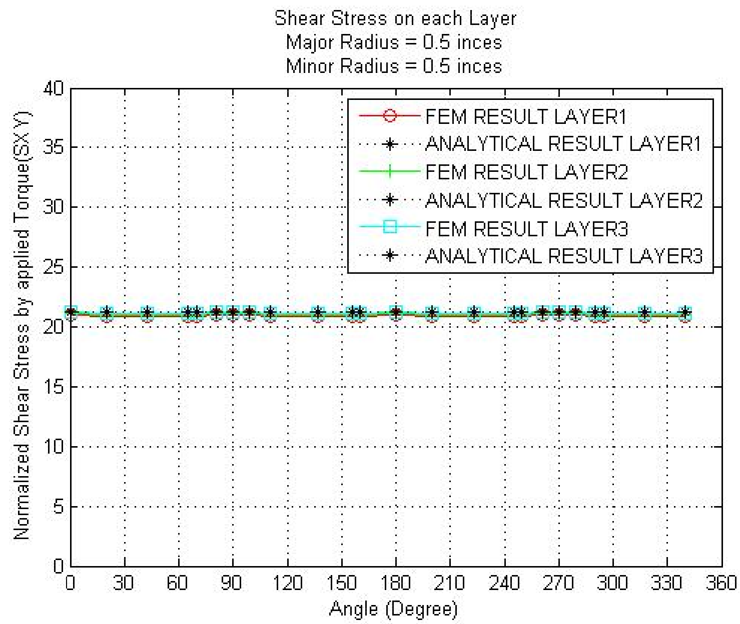


(a)

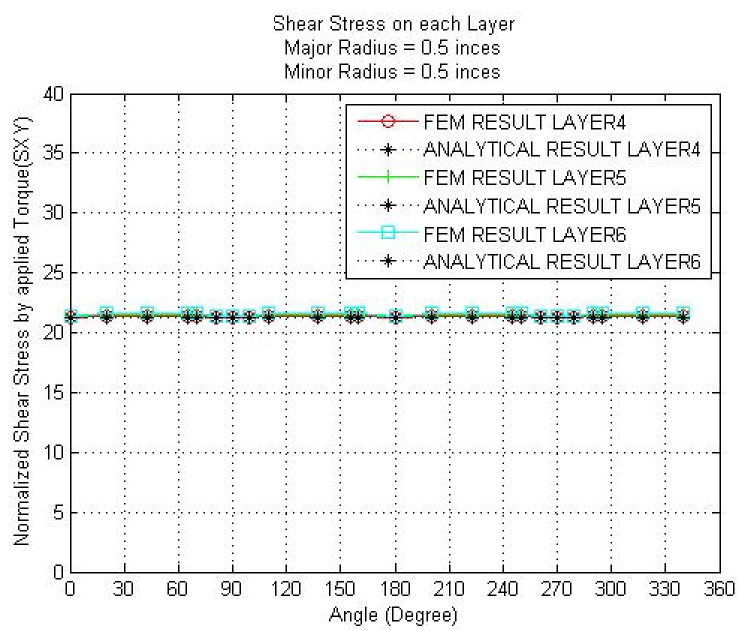


(b)

Figure 4.5 The comparison between FEM and CLPT for $[0]_{6T}$ from layer (a) 1 - 3 and (b) 3 - 6 with $\frac{b}{a} = 0.2$

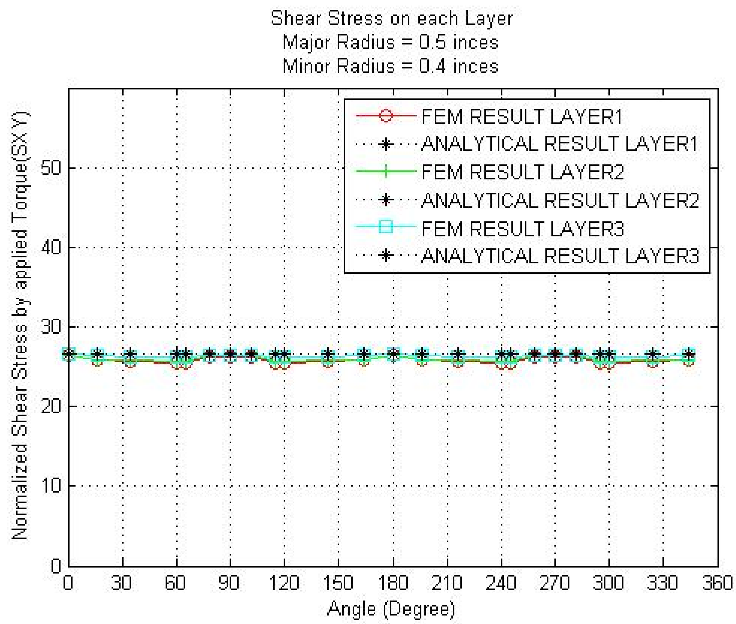


(a)

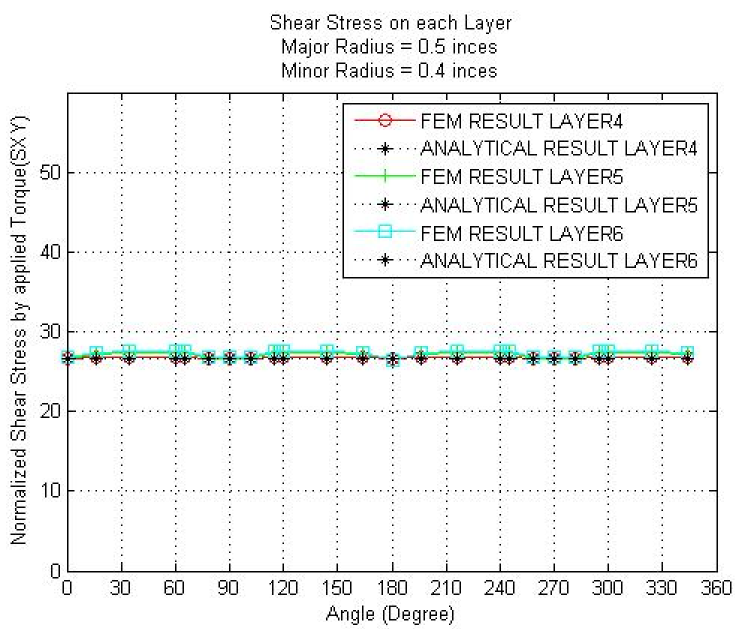


(b)

Figure 4.6 The comparison between FEM and CLPT for $[45]_{6T}$ from layer (a) 1 - 3 and (b) 3 - 6 with $\frac{b}{a} = 1$

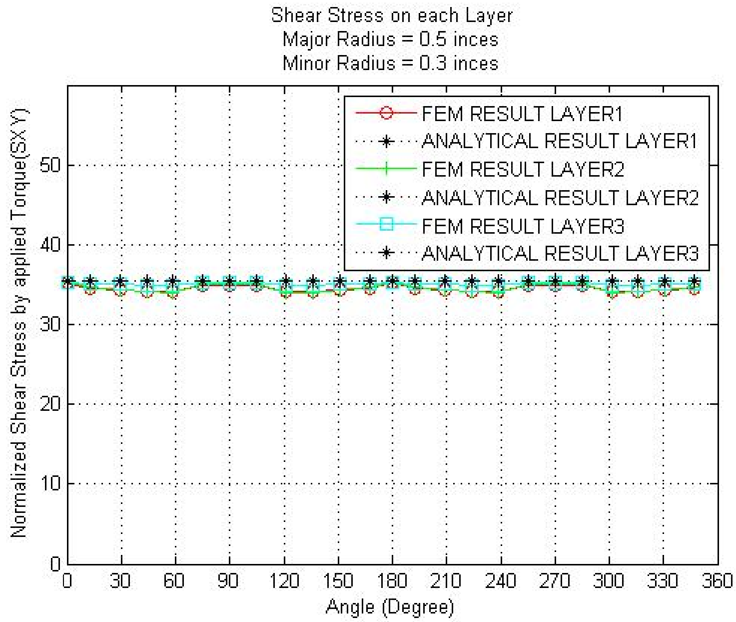


(a)

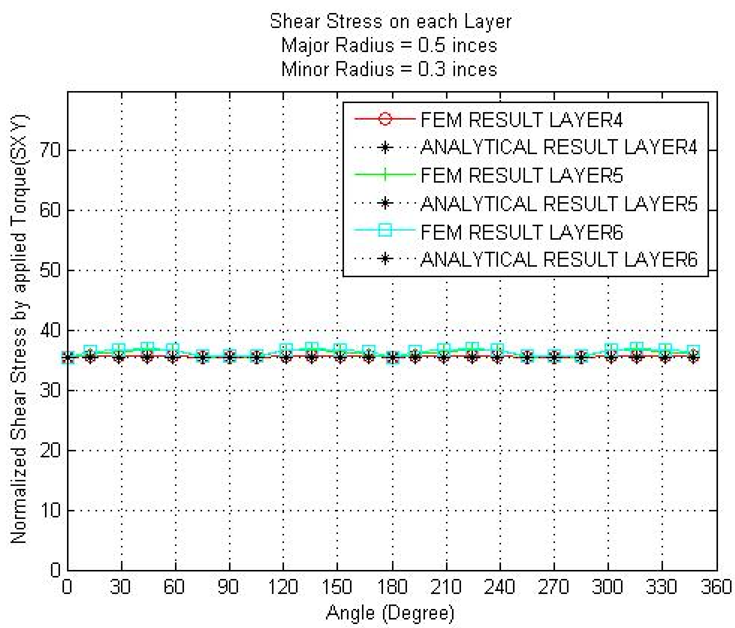


(b)

Figure 4.7 The comparison between FEM and CLPT for $[45]_{6T}$ from layer (a) 1 - 3 and (b) 3 - 6 with $\frac{b}{a} = 0.8$

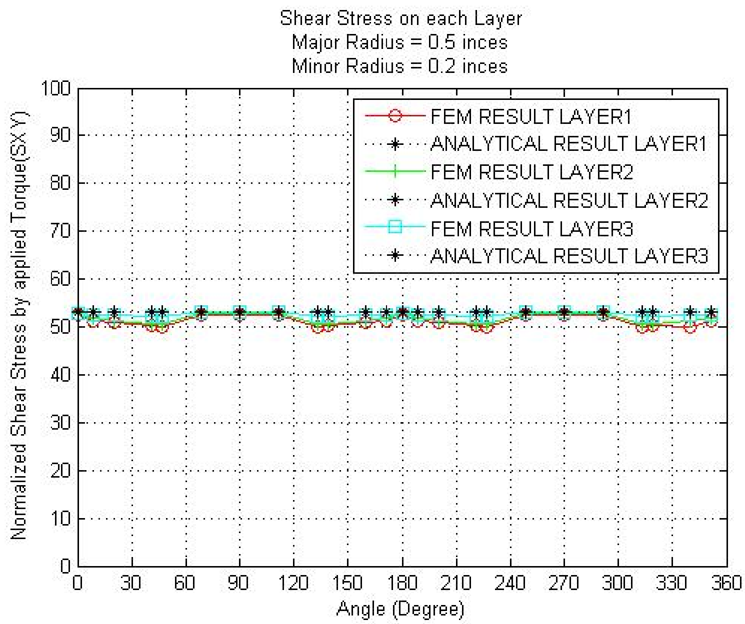


(a)

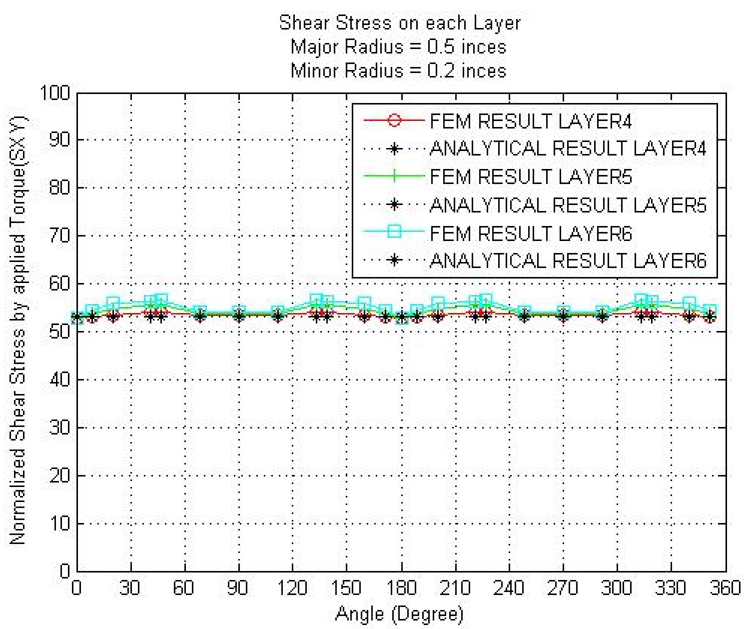


(b)

Figure 4.8 The comparison between FEM and CLPT for $[45]_{6T}$ from layer (a) 1 - 3 and (b) 3 - 6 with $\frac{b}{a} = 0.6$

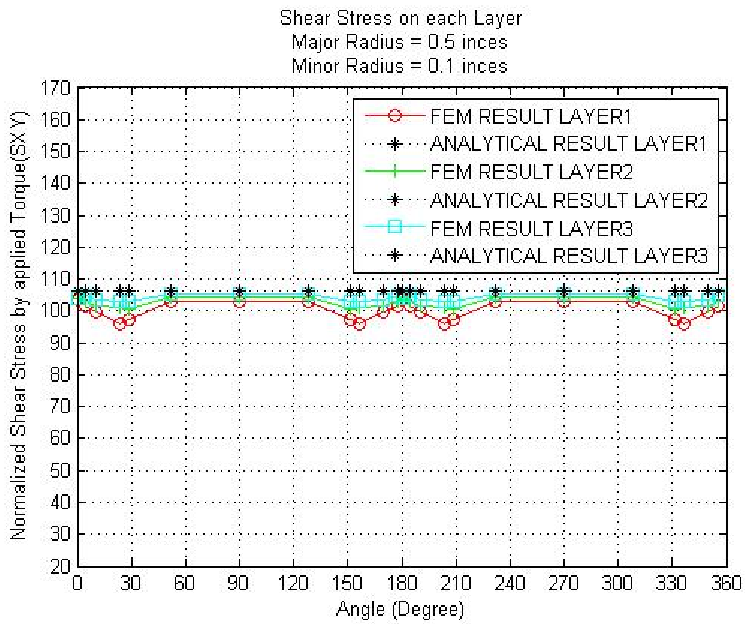


(a)

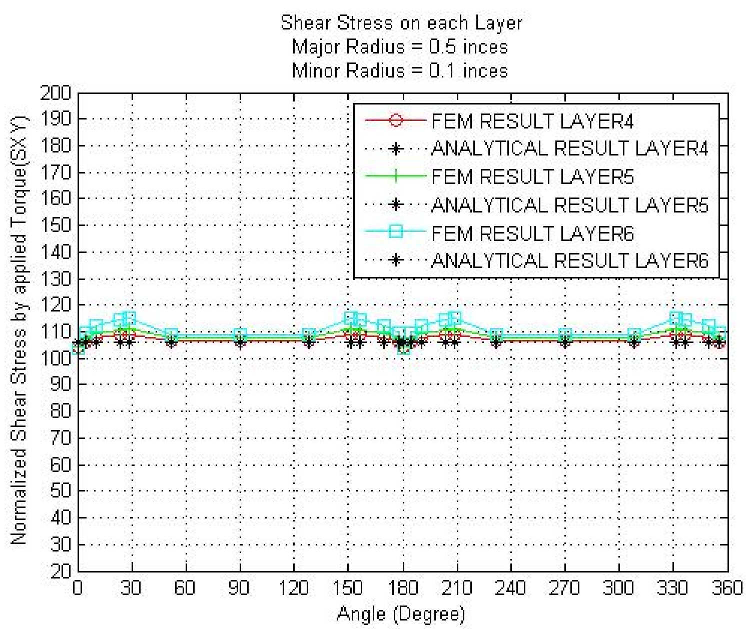


(b)

Figure 4.9 The comparison between FEM and CLPT for $[45]_{6T}$ from layer (a) 1 - 3 and (b) 3 - 6 with $\frac{b}{a} = 0.4$



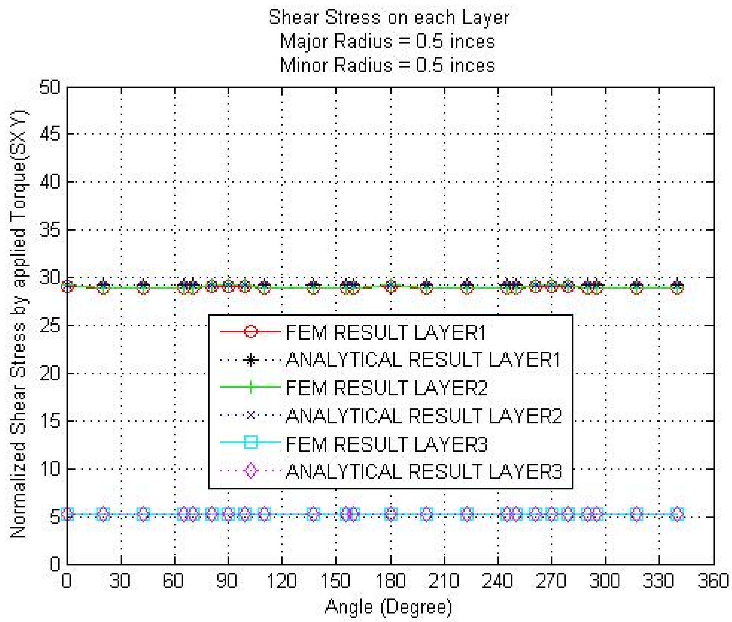
(a)



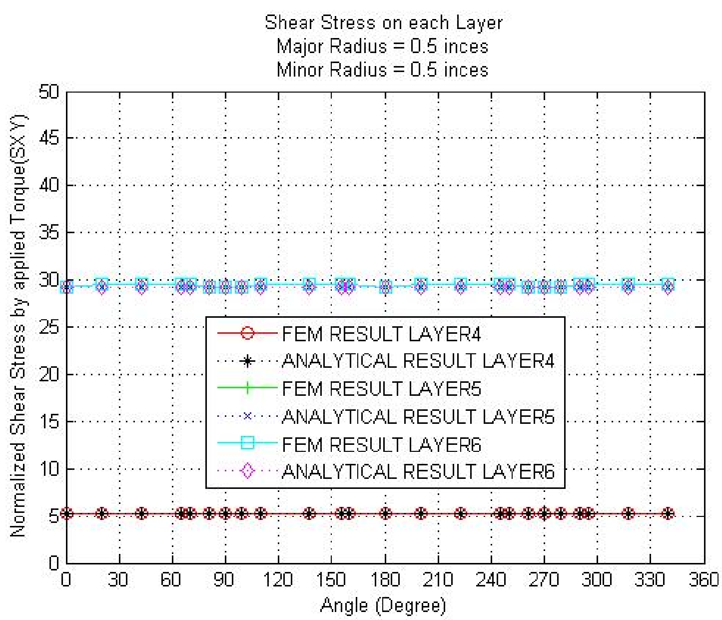
(b)

Figure 4.10 The comparison between FEM and CLPT for $[45]_{6T}$ from layer (a) 1 - 3 and (b) 3 - 6 with $\frac{b}{a} = 0.2$

4.1.2 Symmetric& Balance Multi fiber orientation $[\pm 45/0]_S$



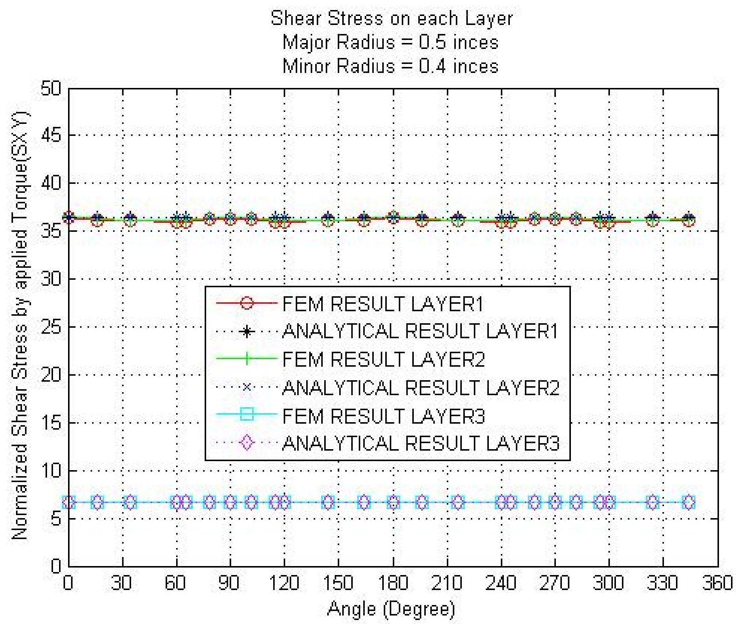
(a)



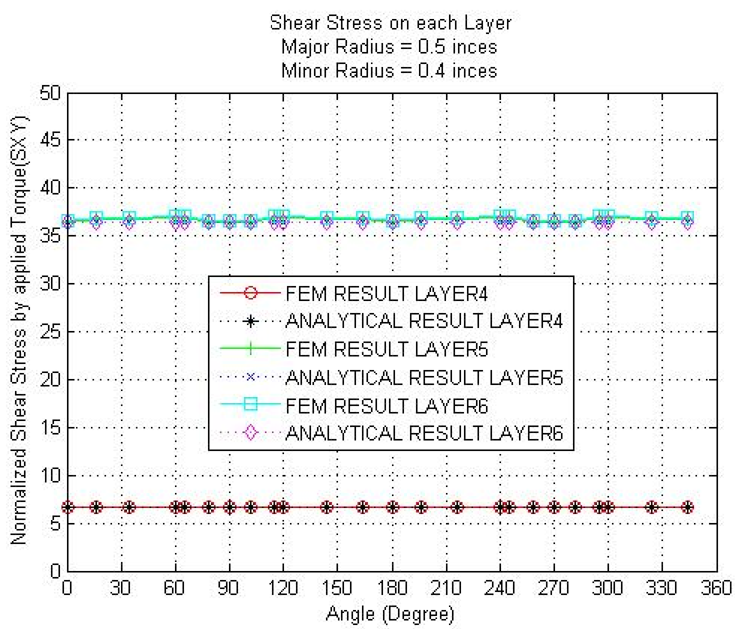
(b)

Figure 4.11 The comparison between FEM and CLPT for $[\pm 45/0]_S$ from layer (a) 1-3 and (b) 3-6

with $\frac{b}{a} = 1$

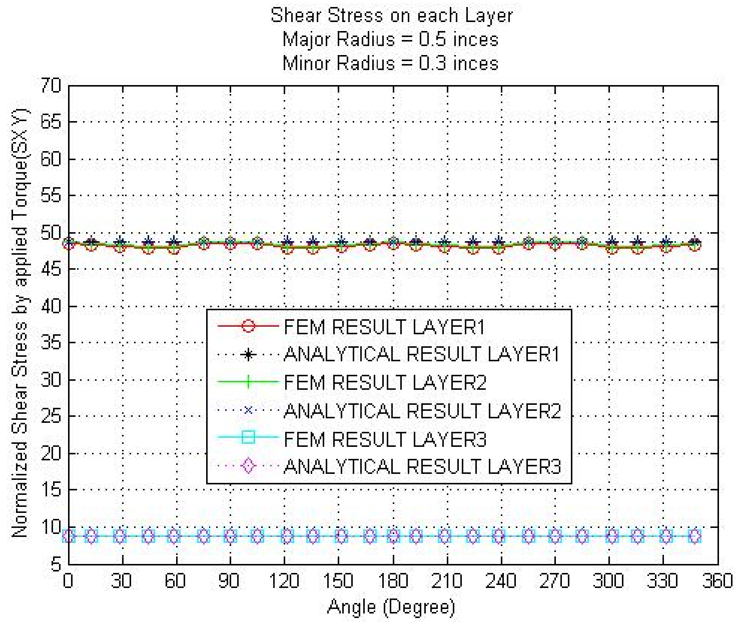


(a)

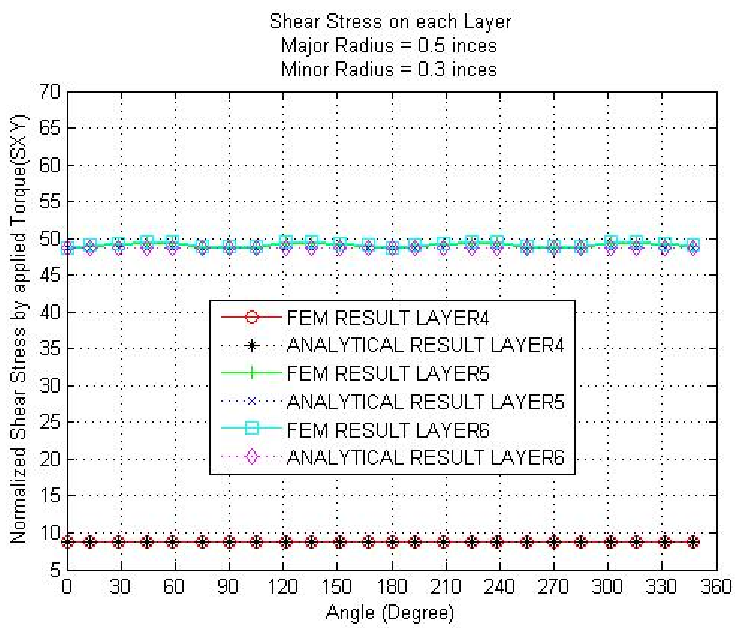


(b)

Figure 4.12 The comparison between FEM and CLPT for $[\pm 45/0]_S$ from layer (a) 1-3 and (b) 3-6 with $\frac{b}{a} = 0.8$

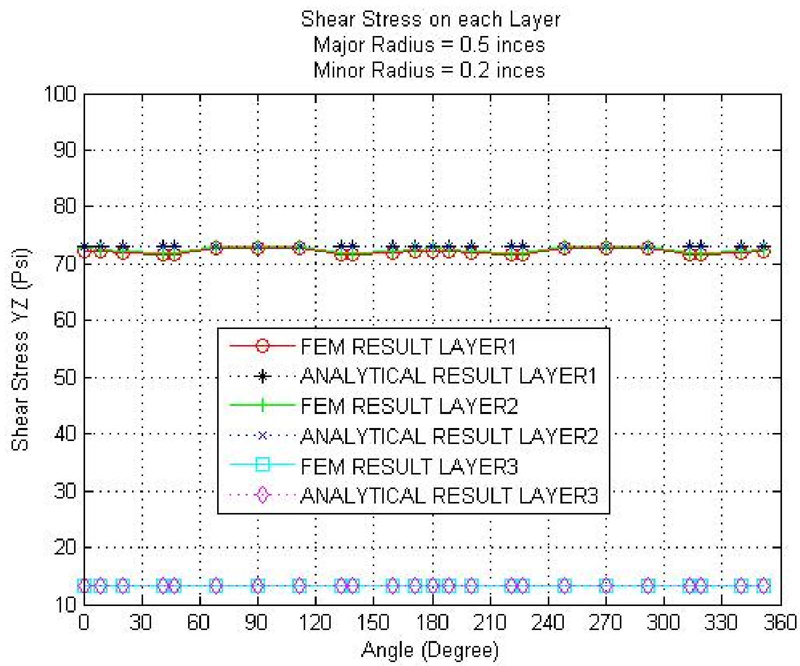


(a)

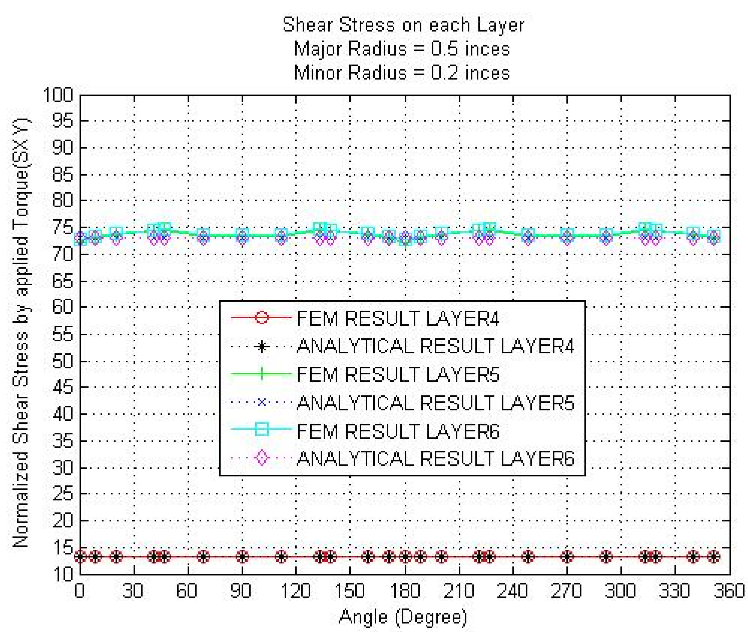


(b)

Figure 4.13 The comparison between FEM and CLPT for $[\pm45/0]_S$ from layer (a) 1-3 and (b) 3-6 with $\frac{b}{a} = 0.6$

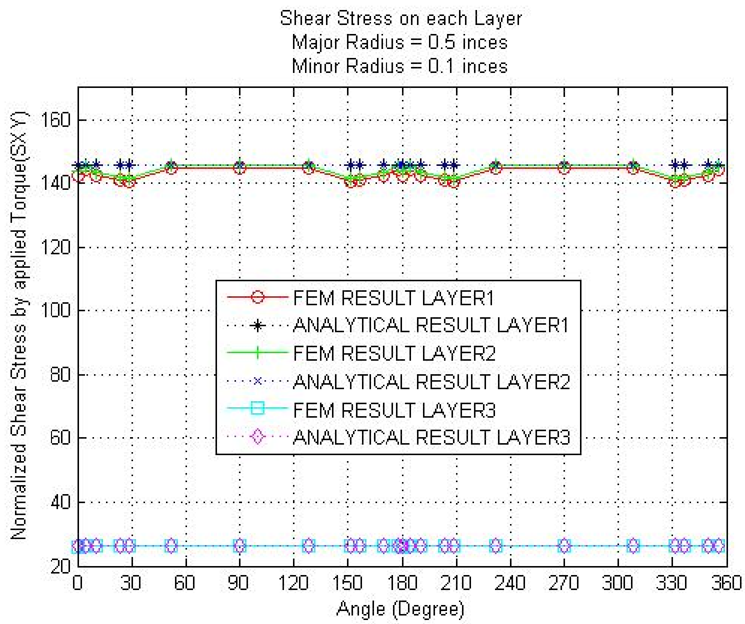


(a)

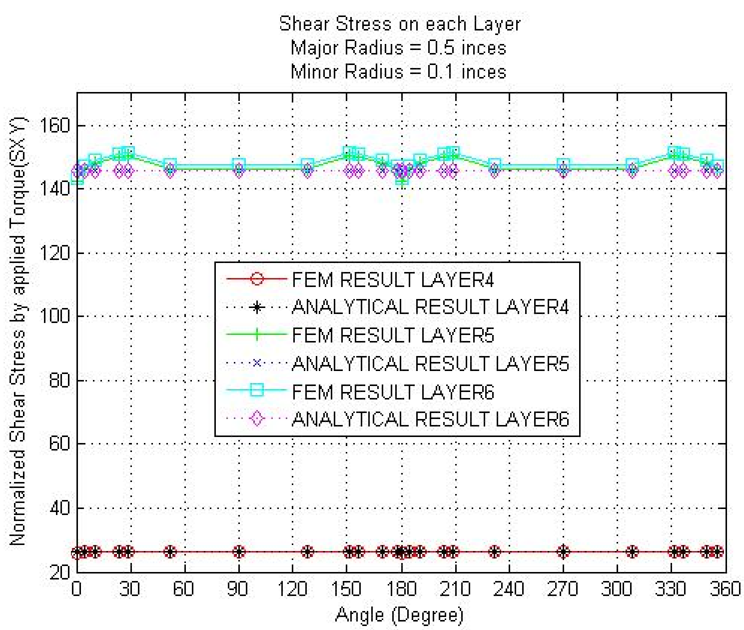


(b)

Figure 4.14 The comparison between FEM and CLPT for $[\pm 45/0]_S$ from layer (a) 1-3 and (b) 3-6 with $\frac{b}{a} = 0.4$



(a)



(b)

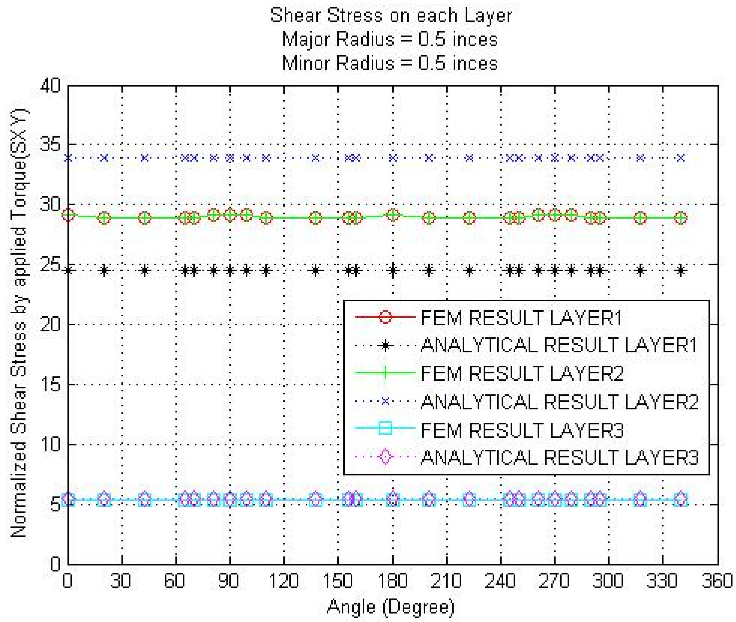
Figure 4.15 The comparison between FEM and CLPT for $[\pm 45/0]_S$ from layer (a) 1-3 and (b) 3-6 with $\frac{b}{a} = 0.2$

The $[\pm45/0]_S$ is symmetric and balance layup. There is no z-displacement in the model and the material orientation does not cause a curvature effect due to varying moduli on either side of the composite centerline. This can also be seen in the composite constitutive matrices by the null extensional-bending stiffness or B matrix. The shear stress results that got from FEM are generally agrees to the CLPT as the previous cases. The miss matches are emerged on 45 and -45 degree ply when the radius ratio is high, $\frac{b}{a} = 0.4$ and, $\frac{b}{a} = 0.2$ on the high curvature region due to the severe configuration.

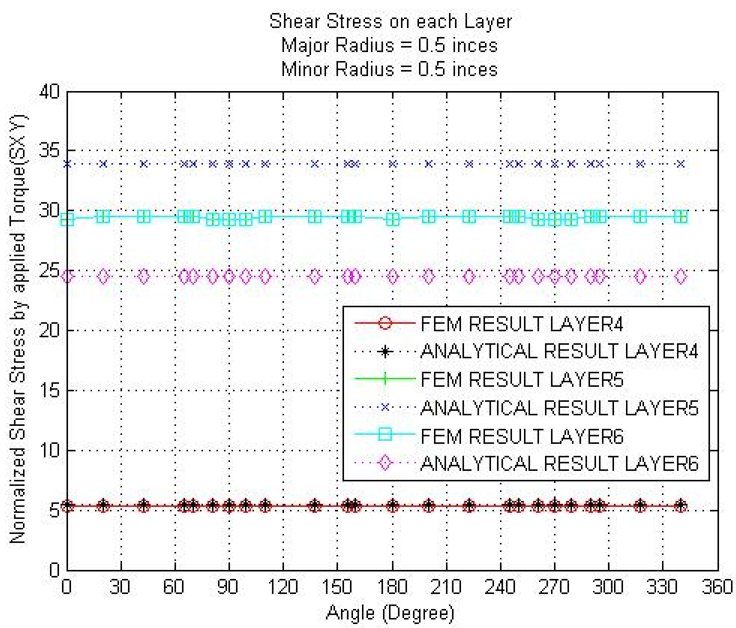
4.2 The comparison results of Unsymmetric layups between FEM and CLPT

4.2.1 Anti-Symmetric & Balanced Multi fiber orientation [+45/-45/0/0/45/-45]

The [+45/-45/0/0/45/-45] is anti-symmetric and balanced layup. The model is now unsymmetrically layered, and the material orientation cause a curvature effect due to varying moduli on either side of the composite centerline. The composite constitutive matrices are no longer zero which means extensional-bending stiffness or B matrix. These caused the miss match of shear stress between FEM and CLPT on the 45 and -45 degree plies which impact from the effect of the extensional-bending stiffness and curvature. The spike pattern appear on the high curvature region when the radius ratio is high for example $\frac{\mathrm{b}}{\mathrm{a}} = 0.4$ and, $\frac{\mathrm{b}}{\mathrm{a}} = 0.2$ because of the effect of curvatures

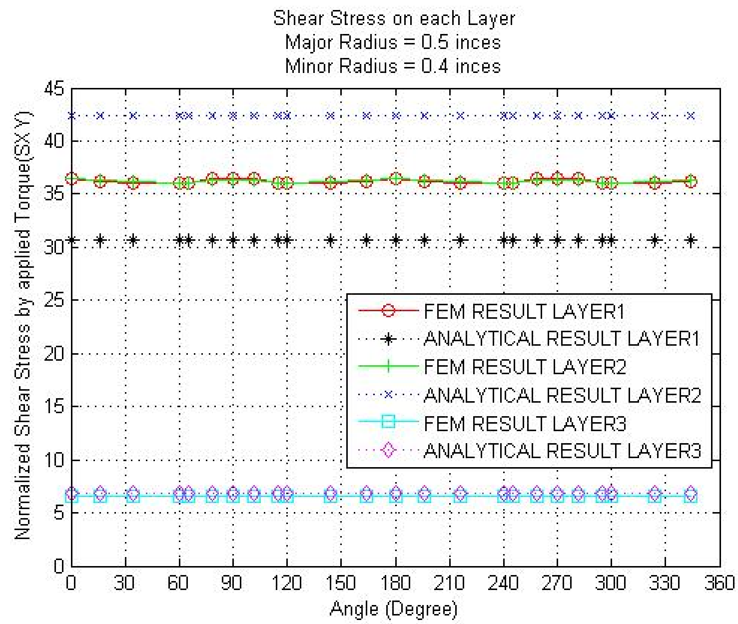


(a)

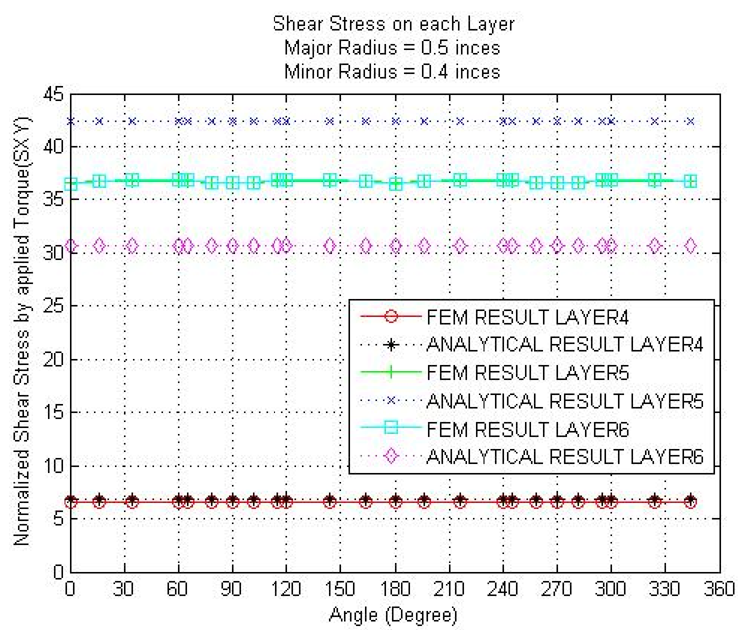


(b)

Figure 4.16 The comparison between FEM and CLPT for [+45/-45/0/0/45/-45] from layer (a) 1-3 and (b) 3-6 with $\frac{b}{a} = 1$

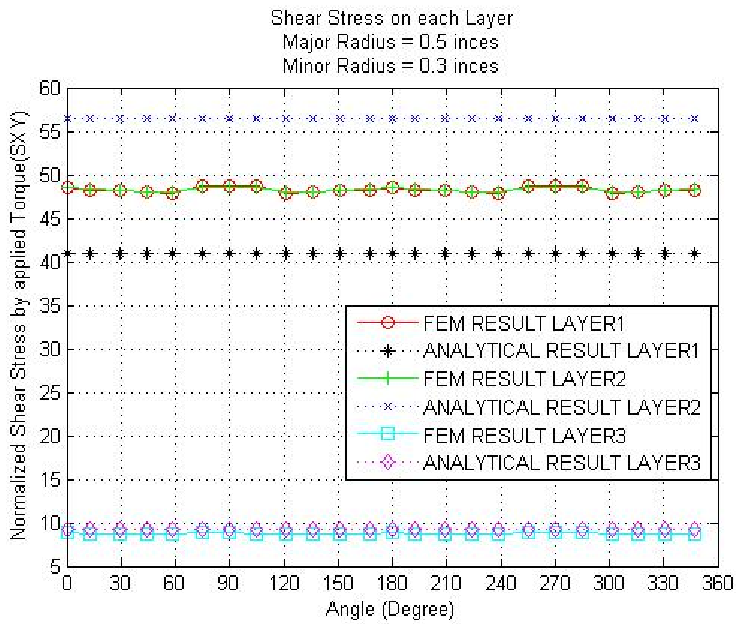


(a)

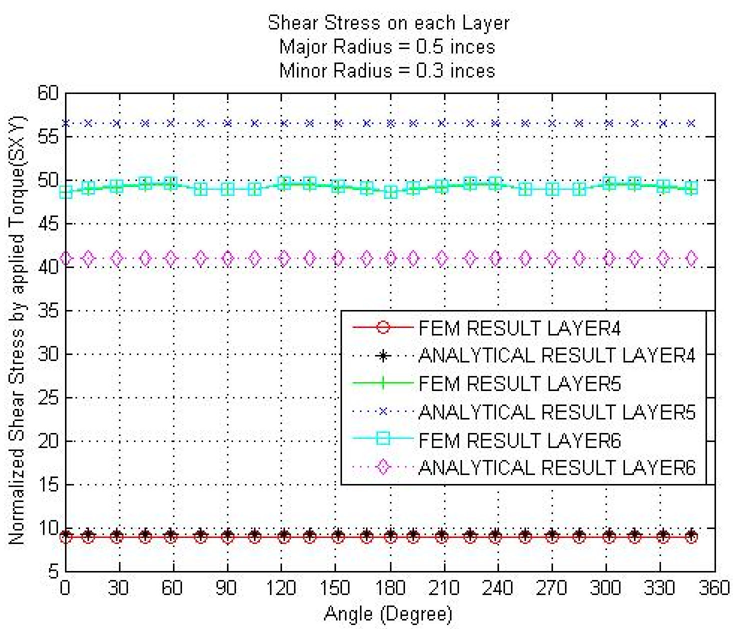


(b)

Figure 4.17 The comparison between FEM and CLPT for [+45/-45/0/0/45/-45] from layer (a) 1-3 and (b) 3-6 with $\frac{b}{a} = 0.8$

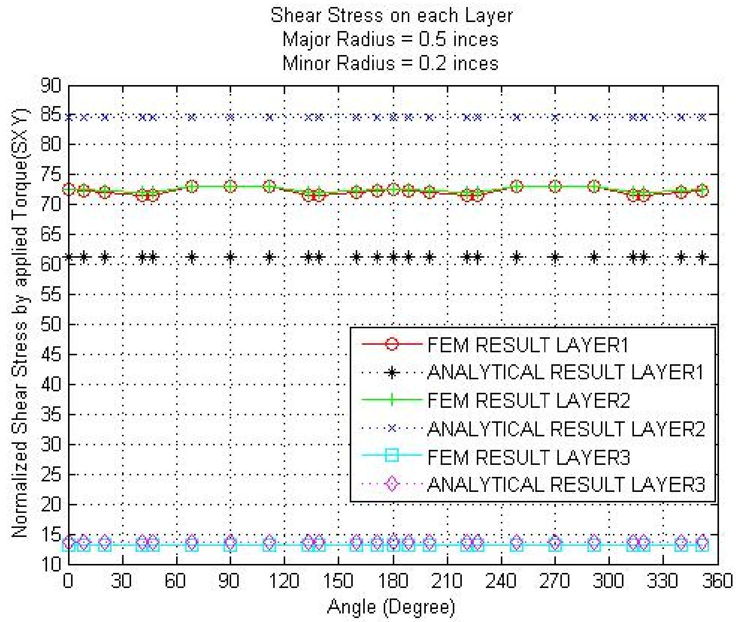


(a)

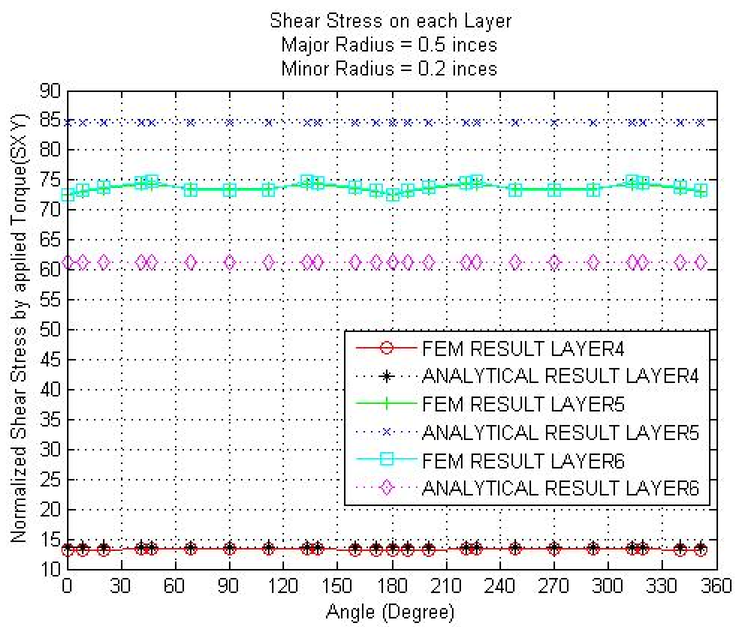


(b)

Figure 4.18 The comparison between FEM and CLPT for [+45/-45/0/0/45/-45] from layer (a) 1-3 and (b) 3-6 with $\frac{b}{a} = 0.6$

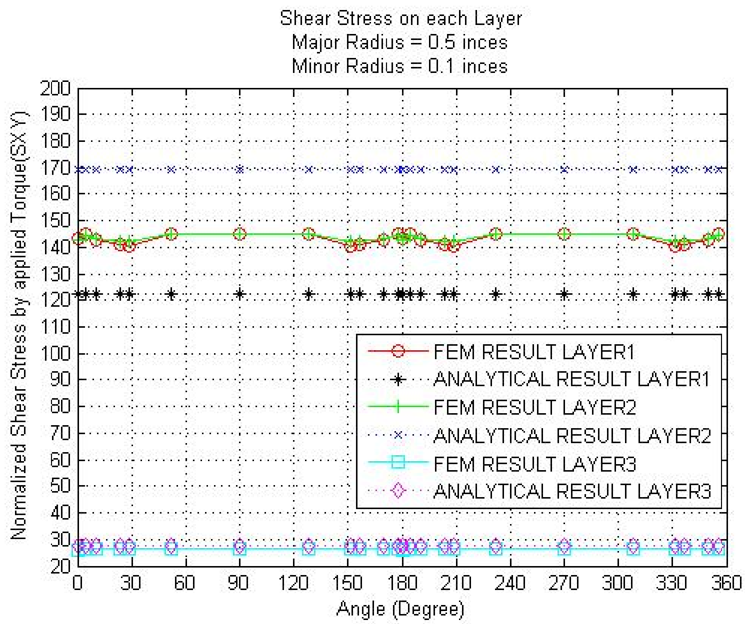


(a)

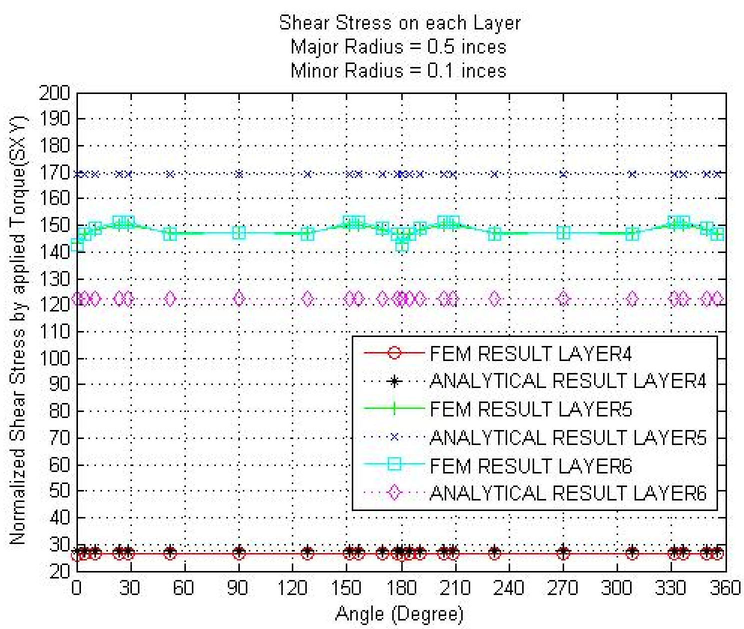


(b)

Figure 4.19 The comparison between FEM and CLPT for [+45/-45/0/0/45/-45] from layer (a) 1-3 and (b) 3-6 with $\frac{b}{a} = 0.4$



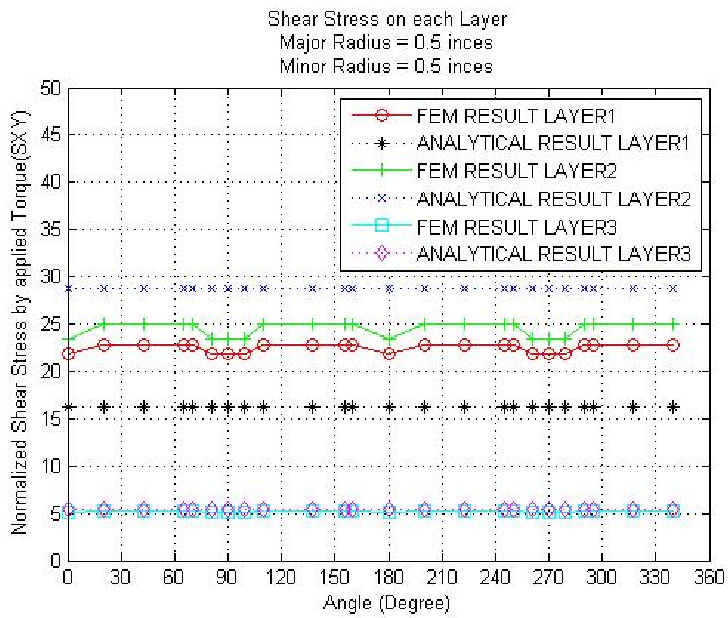
(a)



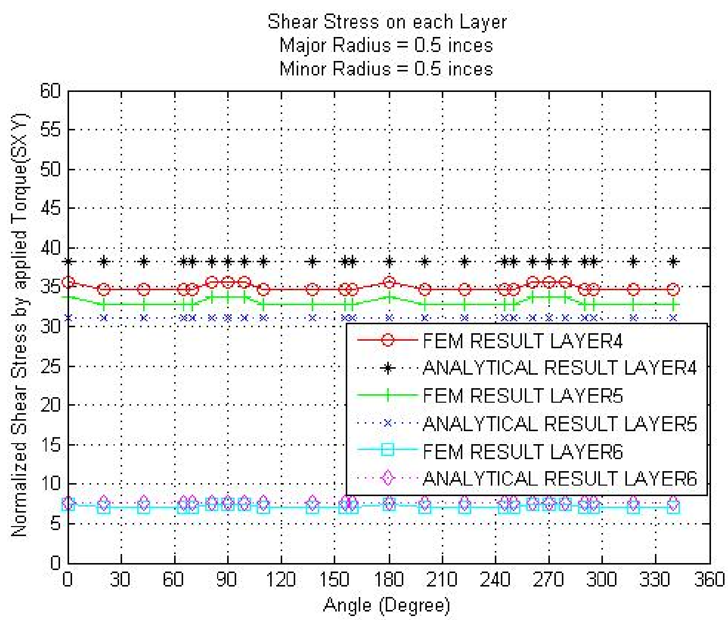
(b)

Figure 4.20 The comparison between FEM and CLPT for [+45/-45/0/0/45/-45] from layer (a) 1-3 and (b) 3-6 with $\frac{b}{a} = 0.2$

4.2.2 Unsymmetric & Balanced Multi fiber orientation $[\pm45/0]_{2T}$



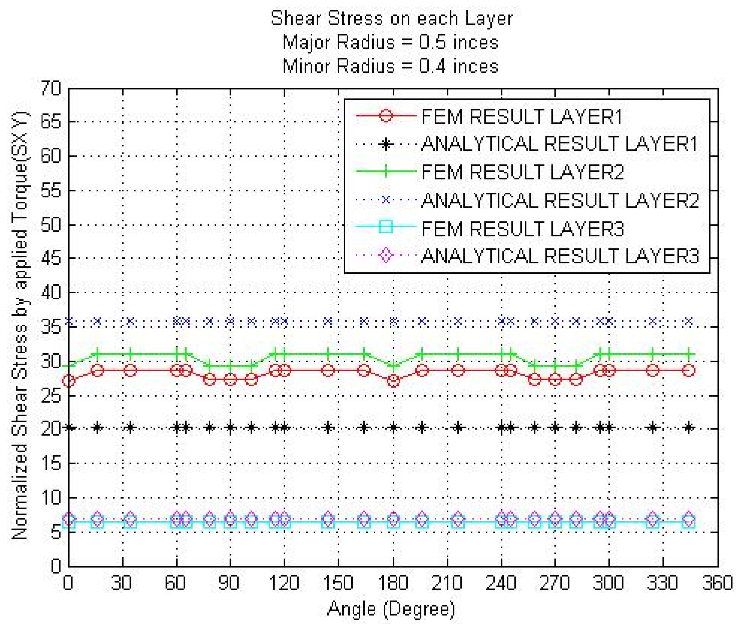
(a)



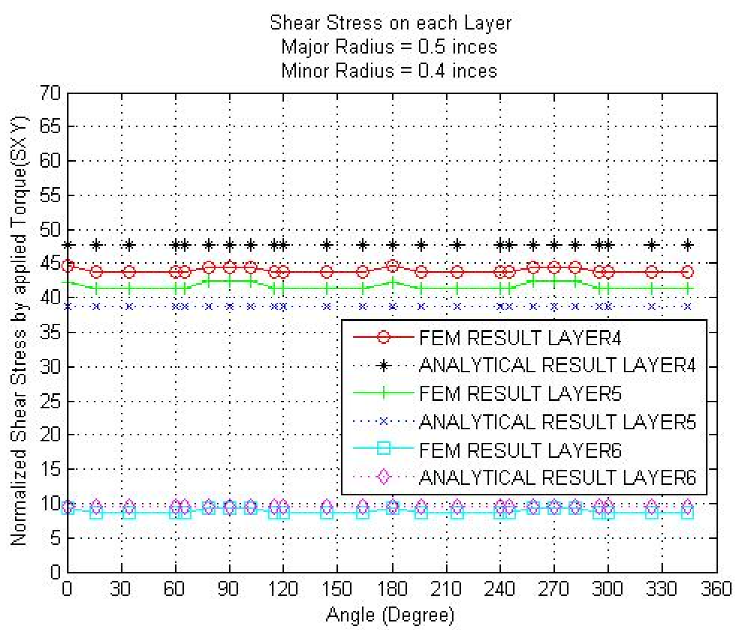
(b)

Figure 4.21 The comparison between FEM and CLPT for $[\pm45/0]_{2T}$ from layer (a) 1-3 and (b) 3-6

with $\frac{b}{a} = 1$



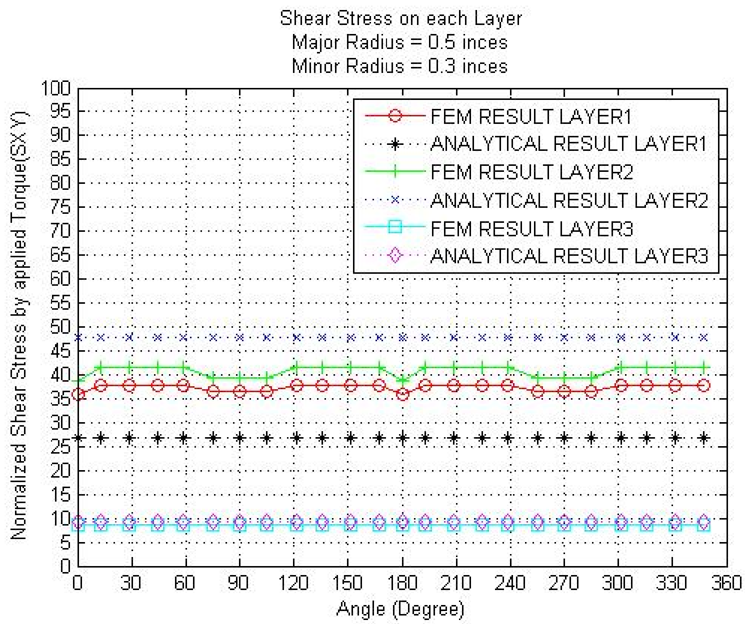
(a)



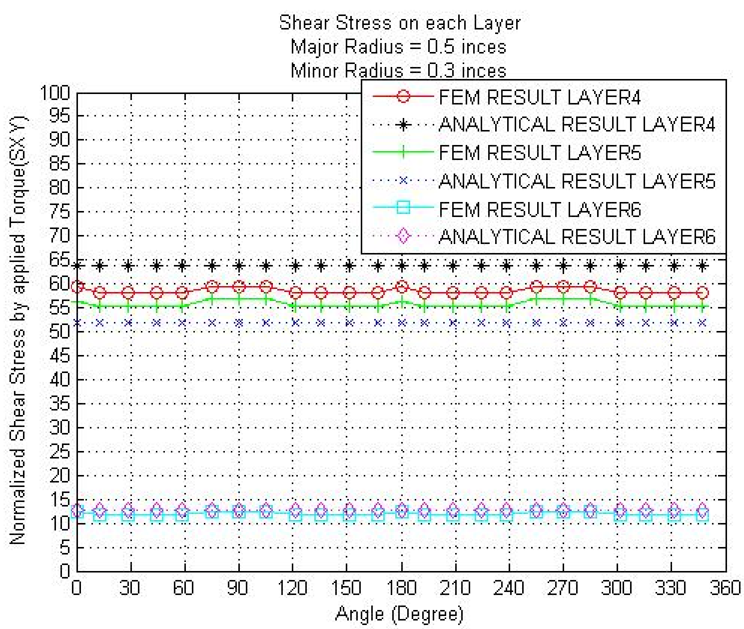
(b)

Figure 4.22 The comparison between FEM and CLPT for $[\pm45/0]_{2T}$ from layer (a) 1-3 and (b) 3-6

with $\frac{b}{a} = 0.8$



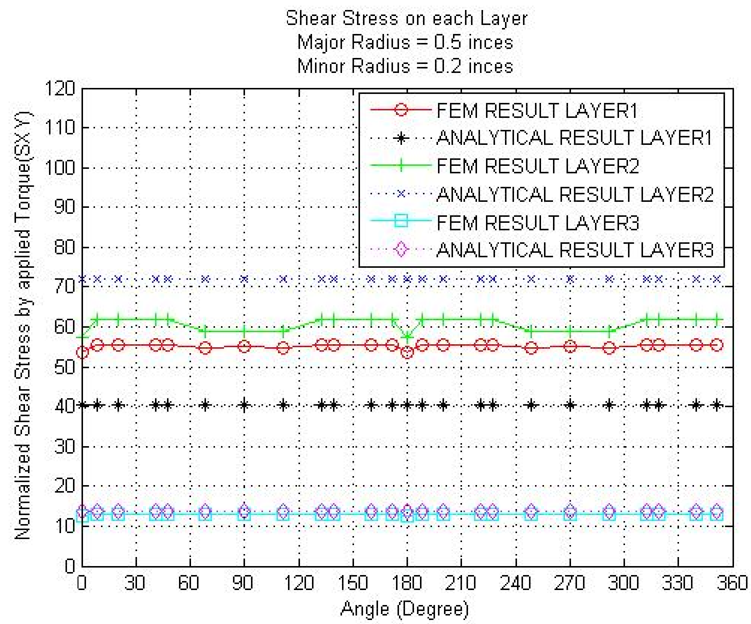
(a)



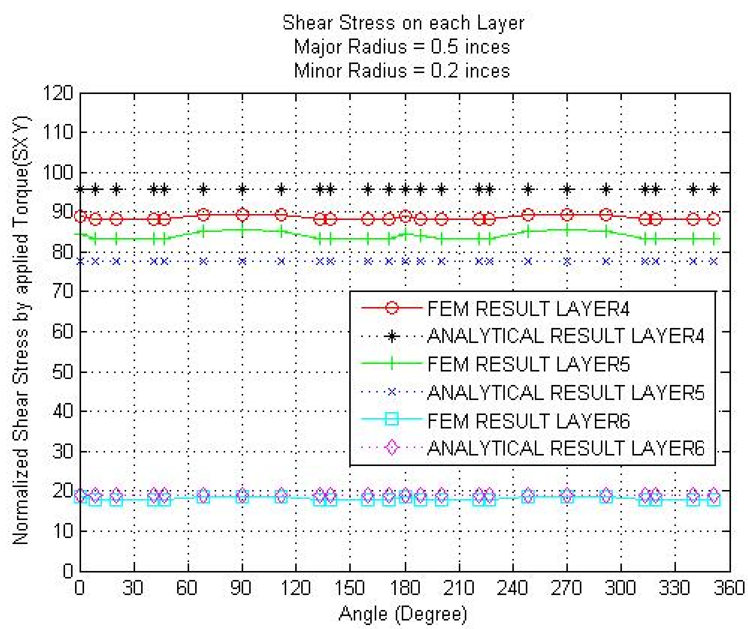
(b)

Figure 4.23 The comparison between FEM and CLPT for $[\pm 45/0]_{2T}$ from layer (a) 1-3 and (b) 3-6

with $\frac{b}{a} = 0.6$

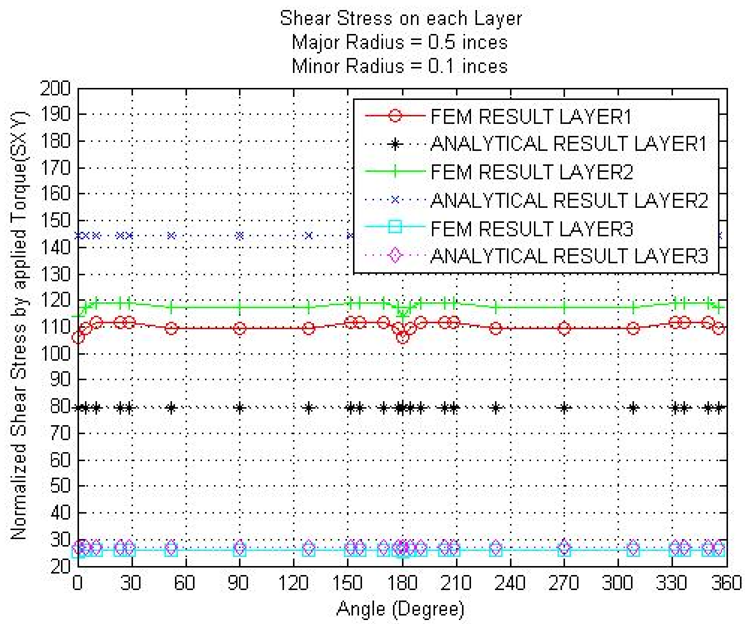


(a)

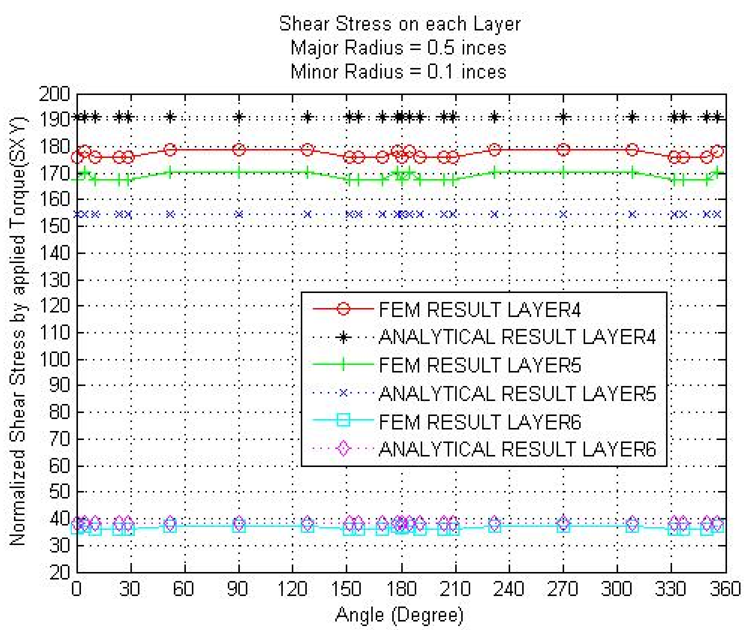


(b)

Figure 4.24 The comparison between FEM and CLPT for $[\pm 45/0]_{2T}$ from layer (a) 1-3 and (b) 3-6 with $\frac{b}{a} = 0.4$



(a)



(b)

Figure 4.25 The comparison between FEM and CLPT for $[\pm 45/0]_{2T}$ from layer (a) 1-3 and (b) 3-6 with $\frac{b}{a} = 0.2$

The $[\pm 45/0]_{2T}$ is unsymmetric and balanced layup. The model is now unsymmetrically layered, and the material orientation cause a curvature effect due to varying moduli on either side of the composite centerline. The composite constitutive matrices are no longer zero which means extensional-bending stiffness or B matrix. These caused the miss match of shear stress between FEM and CLPT on the 45 and -45 degree plies which impact from the effect of the extensional-bending stiffness and curvature. The spike pattern appear on the high curvature region when the radius ratio is high for example $\frac{b}{a} = 0.4$ and, $\frac{b}{a} = 0.2$ because of the effect of curvatures

CHAPTER 5

CONCLUSION AND RECOMMENDATION

The behavior of shear stress was investigated for circular and elliptical laminated tubular cross sections with symmetric and unsymmetrical layups includes change of ply orientation along the circumference of the tube. The results of shear stress are exhibited corresponding to the angle along the circumference of the tube. Several elliptical tubes with different radius ratio are investigated based on a major radius is equal to 0.5in. The results reveal an unusual behavior pattern in the high curvature section of large aspect ratio elliptical cross sections. However, in the circular cross section shape the shear stress are identical to laminated plate theory

The numerical model of laminated tubular structure was developed under the commercial finite element program called ANSYS CLASSIC V.11. The tubular models are validated using isotropic material, aluminum. Shear stress along the tube circumferences with constant thickness are compared by the result of FEM with analytic thin wall under torsion. Shear stresses are identical in circular and elliptical tube with large aspect ratio, 1, 0.8, and 0.6. However, the shear stress result in the elliptical tube with small aspect ratio is about 2.7% off from the theory of thin wall under torsion.

The symmetric layups which includes $[0]_{6T}$, $[45]_{6T}$, and $[\pm 45/0]_S$ were investigated. The results of shear stress in laminated tube with symmetric layups obtained by the finite element method generally agree with those obtained from laminated plate theory because the effect of curvature does not play a significant role in the laminate tube due to the behavior of symmetrical layups. The extensional-bending coupling stiffness matrix is equal to zero. However, when the minor over major radius ratio is getting small the unusual pattern also exist on the high curvature region.

The shear stress in the unsymmetrical case as [45/-45/0_2/45/-45] and [45/-45/0/45/-45/0] which obtained from FEM exhibit the miss match result with the shear stress obtained from CSLP. The miss match exists due to the behavior of unsymmetrical layups that calculating based on laminated plated theory, inducing the effect of curvature due to the extensional-bending coupling stiffness matrix is not equal to zero anymore. However, this effect is not affecting much on the 0 degree ply. Developing the lamination theory under torsion should be developed in the future study based on shell laminated by using this research as a reference. Furthermore, this command code will be used to study tubular structure under thermal effect by applying the thermal condition into the MP command which attached in the APPENDIX C.

APPENDIX A

MATHLAB PROGRAMS FOR LAMINATED PLAT THEORY

```
clc, clear;

%Given Constants%
E1=21.3e6;
E2=1.5e6;
E3=1.5e6;
G12=1.0e6;
G23=0.54e6;
G13=1.0e6;
v12=0.27;
v21=v12*E2/E1;
v23=0.54;
v13=0.27;
t=0.005;

%Compliance Matrix [S]1-2 %
S11=1/E1;
S12=-v21/E2;
S21=-v12/E1;
S22=1/E2;
S66=1/G12;
S14=0; S15=0; S16=0;
S24=0; S25=0; S26=0;
S34=0; S35=0; S36=0;
S41=0; S42=0; S43=0; S45=0; S46=0;
S51=0; S52=0; S53=0; S54=0; S56=0;
S61=0; S62=0; S63=0; S64=0; S65=0;
S=[S11, S12, S16;S21, S22, S26;S61, S62, S66];

%Whole Stiffness Matrix [Q]1-2 %
Q=inv(S)

%Convert [Q]1-2 to [Q_0]x-y%
m1=cos(0); n1=sin(0);
Tstress_0=[m1^2, n1^2, 2*m1*n1; n1^2, m1^2, -2*m1*n1; -m1*n1, m1*n1,
m1^2-n1^2];
Tinvstress_0 = inv(Tstress_0);
Tstrain_0=[m1^2, n1^2, m1*n1; n1^2, m1^2, -m1*n1; -2*m1*n1, 2*m1*n1,
m1^2-n1^2];
Q_0=(Tinvstress_0*Q)*Tstrain_0

%Convert [Q]1-2 to [Q_45]x-y%
m2=cos(pi/4); n2=sin(pi/4);
Tstress_45=[m2^2, n2^2, 2*m2*n2; n2^2, m2^2, -2*m2*n2; -m2*n2, m2*n2,
m2^2-n2^2];
Tinvstress_45= inv(Tstress_45);
Tstrain_45=[m2^2, n2^2, m2*n2; n2^2, m2^2, -m2*n2; -2*m2*n2, 2*m2*n2,
m2^2-n2^2];
Q_45=(Tinvstress_45*Q)*Tstrain_45

%Convert [Q]1-2 to [Q_-45]x-y%
m3=cos(-pi/4); n3=sin(-pi/4);
```

```
Tstress_neg45=[m3^2, n3^2, 2*m3*n3; n3^2, m3^2, -2*m3*n3; -m3*n3,
m3*n3, m3^2-n3^2];
Tinvstress_neg45= inv(Tstress_neg45);
Tstrain_neg45=[m3^2, n3^2, m3*n3; n3^2, m3^2, -m3*n3; -2*m3*n3,
2*m3*n3, m3^2-n3^2];
Q_neg45=(Tinvstress_neg45*Q)*Tstrain_neg45

%Convert [Q]1-2 to [Q_90]x-y%
m4=cos(pi/2); n4=sin(pi/2);
Tstress_90=[m3^2, n3^2, 2*m3*n3; n3^2, m3^2, -2*m3*n3; -m3*n3, m3*n3,
m3^2-n3^2];
Tinvstress_90= inv(Tstress_90);
Tstrain_90=[m3^2, n3^2, m3*n3; n3^2, m3^2, -m3*n3; -2*m3*n3, 2*m3*n3,
m3^2-n3^2];
Q_90=(Tinvstress_90*Q)*Tstrain_90



%Matrix [A];

%For [A] [45/-45/0/0/-45/45]%
A = (Q_45+Q_neg45+Q_0+Q_0+Q_neg45+Q_45)*t

%Matrix [B];
%k14b = 13*t^2;
%k13b = 11*t^2;
%k12b = 9*t^2;
%k11b = 7*t^2;
k6b  = 5*t^2;
k5b  = 3*t^2;
k4b  = t^2;
k3b  = -t^2;
k2b  = -3*t^2;
k1b  = -5*t^2;
%k4b  = -7*t^2;
%k3b  = -9*t^2;
%k2b  = -11*t^2;
%k1b  = -13*t^2;

%For [B] [45/-45/0/0/-45/45]%
B = (Q_45*k1b+Q_neg45*k2b+Q_0*k3b+Q_0*k4b+Q_neg45*k5b+Q_45*k6b)/2

%Matrix [D];
%k14d = 127*t^3;
%k13d = 91*t^3;
%k12d = 61*t^3;
%k11d = 37*t^3;
k6d = 19*t^3;
k5d  = 7*t^3;
k4d  = t^3;
k3d  = t^3;
k2d  = 7*t^3;
```

```
k1d  = 19*t^3;
%k4d  = 37*t^3;
%k3d  = 61*t^3;
%k2d  = 91*t^3;
%k1d  = 127*t^3;

%For [D] [45/-45/0/90/90/0/-45/45]%
D = (Q_45*k1d+Q_neg45*k2d+Q_0*k3d+Q_0*k4d+Q_neg45*k5d+Q_45*k6d)/3

%Matrix [a], [b], and [d]%
Z = D-(B/A)*B;
a = inv(A)-(-inv(A)*B)*inv(Z)*(B*inv(A));
b = (-inv(A)*B)*inv(Z);
c = b';
d = inv(Z);

ABD = [A B; B D];
abd = [a b; b d];

%Calculate N_th and M_th
syms Nx Ny Nxy Kx Ky Kxy Mx My Mxy z;
Nx=0; Ny=0; Nxy=0.637; Kx=0; Ky=0; Kxy=0; Mx=0; My=0; Mxy=0;

%Calculated Epsilon(0) and Curvature%
N  =[Nx;Ny;Nxy]
M  =[Mx;My;Mxy]
e_0=[a b]*[N; M]
k  =[b d]*[N; M]

%Calculated Principle Strain%
Strain_45_TOP6 = e_0+(0.005*3)*k
Strain_45_BOT6 = e_0+(0.005*2)*k

Strain_neg45_TOP5 = e_0+(0.005*2)*k
Strain_neg45_BOT5 = e_0+(0.005)*k

Strain_0_TOP4 = e_0+(0.005)*k
Strain_0_BOT4 = e_0

Strain_0_TOP3 = e_0
Strain_0_BOT3 = e_0+(-0.005)*k

Strain_neg45_TOP2 = e_0+(-0.005)*k
Strain_neg45_BOT2 = e_0+(-0.005*2)*k

Strain_45_TOP1 = e_0+(-0.005*2)*k
Strain_45_BOT1 = e_0+(-0.005*3)*k
%-------------------------------------------------------------------%

%Calculated Principle Stress%
Stress_45_TOP6 =Q_45*Strain_45_TOP6
```

```
Stress_45_BOT6 =Q_45*Strain_45_BOT6
Stress_neg45_TOP5 = Q_neg45*Strain_neg45_TOP5
Stress_neg45_BOT5 = Q_neg45*Strain_neg45_BOT5

Stress_0_TOP4 = Q_0*Strain_0_TOP4
Stress_0_BOT4 = Q_0*Strain_0_BOT4

Stress_0_TOP3 = Q_0*Strain_0_TOP3
Stress_0_BOT3 = Q_0*Strain_0_BOT3

Stress_neg45_TOP2 = Q_neg45*Strain_neg45_TOP2
Stress_neg45_BOT2 = Q_neg45*Strain_neg45_BOT2

Stress_45_TOP1 = Q_45*Strain_45_TOP1
Stress_45_BOT1 = Q_45*Strain_45_BOT1
%-------------------------------------------------------------------%
```

APPENDIX B

FINITE ELEMENT CODE : ANSYS V.11 PROGRAMS

```
FINISH
/CLEAR
/FILNAME,SYMETRY
/TITLE,Tubular Stracture Under Torsion
/prep7
/OUTPUT, CCT, OUT,
!! Basic Parameter Setup !!
*SET,radi,0.5
*SET,semiradi,0.1
*SET,length,5
*SET,t,0.005   !---------*
*SET,torque,1
*SET,force,2

!! Material Properties Setup!!
et,1,shell99
mp,ex,1,21.3e6
mp,ey,1,1.5e6
mp,ez,1,1.5e6
mp,prxy,1,0.27
mp,prxz,1,0.27
mp,pryz,1,0.54
mp,gxy,1,1e6
mp,gyz,1,0.54e6
mp,gxz,1,1e6
keyopt,1,2,0
keyopt,1,3,0
keyopt,1,4,0
keyopt,1,5,2
keyopt,1,6,5
keyopt,1,8,1
keyopt,1,9,0
keyopt,1,10,0
keyopt,1,11,0

r,1
RMODIF,1,1,6,
RMODIF,1,13,    1, 45, t,
RMODIF,1,16,    1, -45, t,
RMODIF,1,19,    1,   0, t,
RMODIF,1,22,    1,   0, t,
RMODIF,1,25,    1, -45, t,
RMODIF,1,28,    1,  45, t,

!! Coordinate  Preparation !!
local,11,1,,,,,,,semiradi/radi
CSYS,11
K,1:80,radi,0:360:4.5

!! Laminated Tube Modeling !!
k,100001,0,0,0
```

```
k,100002,0,0,length

*do,i,1,79,1
bsplin,i,i+1
*enddo
bsplin,80,1

lglue,all
al,all
VOFFST,1,length, ,
VDELE,1
ADELE,1,2
AGLUE,ALL

lsel,s,length,,length,,,0
lesize,all,,,80
cm,sideline,line
allsel,all,line
nkpt,,100001
nkpt,,100002
amesh,all
nrotat,all

nsel,s,loc,z,0
nsel,u,node,1
d,all,ux,0
d,all,uy,0
d,all,uz,0
d,all,rotx,0
d,all,roty,0
d,all,rotz,0
allsel

!! Apply Loading Condition !!
et,2,MPC184
keyopt,2,1,1
keyopt,2,2,1
type,2
real,2
E,2,      8
E,2,      168
E,2,      169
E,2,      170
E,2,      171
E,2,      652
E,2,      812
E,2,      813
E,2,      814
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E,2,     1296
E,2,     1297
E,2,     1298
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E,2,    37114
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E,2,    37598
E,2,    37920
E,2,    38080
E,2,    38081
E,2,    38082
E,2,    38403
E,2,    38404
E,2,    38405
f,2,mz,torque
allsel,all
```

APPENDIX C

SHEAR STRESS RESLTS ALONG CIRCUMFERENCES

Table C.1 Comparison of τ_{xy} along the mid cross-section of the tube for layer 1, 2, 3 and stacking sequence is $[0]_{6T}$ between FEM and CLPT with $\frac{b}{a} = 1$

	SXYLAYER 1			SXYLAYER 2			SXYLAYER 3		
ANGLE (deg)	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**
0	21.101	21.2333	0.6230779	21.16	21.2333	0.34521247	21.214	21.2333	0.09089496
20.25	20.906	21.2333	1.54144669	20.991	21.2333	1.14113209	21.085	21.2333	0.69843124
42.75	20.906	21.2333	1.54144669	20.991	21.2333	1.14113209	21.085	21.2333	0.69843124
65.25	20.906	21.2333	1.54144669	20.991	21.2333	1.14113209	21.085	21.2333	0.69843124
69.75	20.906	21.2333	1.54144669	20.991	21.2333	1.14113209	21.085	21.2333	0.69843124
81	21.101	21.2333	0.6230779	21.16	21.2333	0.34521247	21.214	21.2333	0.09089496
90	21.101	21.2333	0.6230779	21.16	21.2333	0.34521247	21.214	21.2333	0.09089496
99	21.101	21.2333	0.6230779	21.16	21.2333	0.34521247	21.214	21.2333	0.09089496
110.25	20.906	21.2333	1.54144669	20.991	21.2333	1.14113209	21.085	21.2333	0.69843124
137.25	20.906	21.2333	1.54144669	20.991	21.2333	1.14113209	21.085	21.2333	0.69843124
155.75	20.906	21.2333	1.54144669	20.991	21.2333	1.14113209	21.085	21.2333	0.69843124
159.75	20.906	21.2333	1.54144669	20.991	21.2333	1.14113209	21.085	21.2333	0.69843124
180	21.101	21.2333	0.6230779	21.16	21.2333	0.34521247	21.214	21.2333	0.09089496
200.25	20.906	21.2333	1.54144669	20.991	21.2333	1.14113209	21.085	21.2333	0.69843124
222.75	20.906	21.2333	1.54144669	20.991	21.2333	1.14113209	21.085	21.2333	0.69843124
245.25	20.906	21.2333	1.54144669	20.991	21.2333	1.14113209	21.085	21.2333	0.69843124
249.75	20.906	21.2333	1.54144669	20.991	21.2333	1.14113209	21.085	21.2333	0.69843124
261	21.101	21.2333	0.6230779	21.16	21.2333	0.34521247	21.214	21.2333	0.09089496
270	21.101	21.2333	0.6230779	21.16	21.2333	0.34521247	21.214	21.2333	0.09089496
279	21.101	21.2333	0.6230779	21.16	21.2333	0.34521247	21.214	21.2333	0.09089496
290.25	20.906	21.2333	1.54144669	20.991	21.2333	1.14113209	21.085	21.2333	0.69843124

Table C.1 – *Continued*

294.75	20.906	21.2333	1.54144669	20.991	21.2333	1.14113209	21.085	21.2333	0.69843124
317.25	20.906	21.2333	1.54144669	20.991	21.2333	1.14113209	21.085	21.2333	0.69843124
339.75	20.906	21.2333	1.54144669	20.991	21.2333	1.14113209	21.085	21.2333	0.69843124

Table C.2 Comparison of τ_{xy} along the mid cross-section of the tube for layer 4, 5, 6 and stacking sequence is $[0]_{6T}$ between FEM and CLPT with $\frac{b}{a} = 1$

	SXYLAYER 4			SXYLAYER 5			SXYLAYER 6		
ANGLE (deg)	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**
0	21.263	21.2333	-0.1398746	21.306	21.2333	-0.3423867	21.344	21.2333	-0.5213509
20.25	21.379	21.2333	-0.6861863	21.404	21.2333	-0.8039259	21.468	21.2333	-1.1053393
42.75	21.379	21.2333	-0.6861863	21.404	21.2333	-0.8039259	21.468	21.2333	-1.1053393
65.25	21.379	21.2333	-0.6861863	21.404	21.2333	-0.8039259	21.468	21.2333	-1.1053393
69.75	21.379	21.2333	-0.6861863	21.404	21.2333	-0.8039259	21.468	21.2333	-1.1053393
81	21.263	21.2333	-0.1398746	21.306	21.2333	-0.3423867	21.344	21.2333	-0.5213509
90	21.263	21.2333	-0.1398746	21.306	21.2333	-0.3423867	21.344	21.2333	-0.5213509
99	21.263	21.2333	-0.1398746	21.306	21.2333	-0.3423867	21.344	21.2333	-0.5213509
110.25	21.379	21.2333	-0.6861863	21.404	21.2333	-0.8039259	21.468	21.2333	-1.1053393
137.25	21.379	21.2333	-0.6861863	21.404	21.2333	-0.8039259	21.468	21.2333	-1.1053393
155.75	21.379	21.2333	-0.6861863	21.404	21.2333	-0.8039259	21.468	21.2333	-1.1053393
159.75	21.379	21.2333	-0.6861863	21.404	21.2333	-0.8039259	21.468	21.2333	-1.1053393
180	21.263	21.2333	-0.1398746	21.306	21.2333	-0.3423867	21.344	21.2333	-0.5213509
200.25	21.379	21.2333	-0.6861863	21.404	21.2333	-0.8039259	21.468	21.2333	-1.1053393
222.75	21.379	21.2333	-0.6861863	21.404	21.2333	-0.8039259	21.468	21.2333	-1.1053393
245.25	21.379	21.2333	-0.6861863	21.404	21.2333	-0.8039259	21.468	21.2333	-1.1053393
249.75	21.379	21.2333	-0.6861863	21.404	21.2333	-0.8039259	21.468	21.2333	-1.1053393

Table C.2 – *Continued*

261	21.263	21.2333	-0.1398746	21.306	21.2333	-0.3423867	21.344	21.2333	-0.5213509
270	21.263	21.2333	-0.1398746	21.306	21.2333	-0.3423867	21.344	21.2333	-0.5213509
279	21.263	21.2333	-0.1398746	21.306	21.2333	-0.3423867	21.344	21.2333	-0.5213509
290.25	21.379	21.2333	-0.6861863	21.404	21.2333	-0.8039259	21.468	21.2333	-1.1053393
294.75	21.379	21.2333	-0.6861863	21.404	21.2333	-0.8039259	21.468	21.2333	-1.1053393
317.25	21.379	21.2333	-0.6861863	21.404	21.2333	-0.8039259	21.468	21.2333	-1.1053393
339.75	21.379	21.2333	-0.6861863	21.404	21.2333	-0.8039259	21.468	21.2333	-1.1053393

Table C.3 Comparison of τ_{xy} along the mid cross-section of the tube for layer 1, 2, 3 and stacking sequence is $[0]_{6T}$ between FEM and CLPT with $\frac{b}{a} = 0.8$

	SXYLAYER 1			**SXYLAYER 2**			**SXYLAYER 3**		
ANGLE (deg)	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**
0	26.358	26.5333	0.66067922	26.427	26.5333	0.40062864	26.486	26.5333	0.17826656
16.432	25.678	26.5333	3.22349651	26.012	26.5333	1.96470096	26.345	26.5333	0.70967426
34.46	25.611	26.5333	3.47600939	25.98	26.5333	2.08530413	26.35	26.5333	0.69083001
60.03	25.552	26.5333	3.69837148	25.955	26.5333	2.17952535	26.359	26.5333	0.65691037
65.23	25.544	26.5333	3.72852227	25.952	26.5333	2.1908319	26.36	26.5333	0.65314152
78.8	26.393	26.5333	0.52876951	26.475	26.5333	0.21972389	26.55	26.5333	-0.0629398
90	26.394	26.5333	0.52500066	26.476	26.5333	0.21595505	26.552	26.5333	-0.0704775
101.2	26.393	26.5333	0.52876951	26.475	26.5333	0.21972389	26.55	26.5333	-0.0629398
114.77	25.544	26.5333	3.72852227	25.952	26.5333	2.1908319	26.36	26.5333	0.65314152
119.97	25.552	26.5333	3.69837148	25.955	26.5333	2.17952535	26.359	26.5333	0.65691037
143.54	25.611	26.5333	3.47600939	25.98	26.5333	2.08530413	26.35	26.5333	0.69083001
163.57	25.678	26.5333	3.22349651	26.012	26.5333	1.96470096	26.345	26.5333	0.70967426
180	26.358	26.5333	0.66067922	26.427	26.5333	0.40062864	26.486	26.5333	0.17826656

Table C.3 – *Continued*

196.43	25.678	26.5333	3.22349651	26.012	26.5333	1.96470096	26.345	26.5333	0.70967426
216.46	25.611	26.5333	3.47600939	25.98	26.5333	2.08530413	26.35	26.5333	0.69083001
240.03	25.552	26.5333	3.69837148	25.955	26.5333	2.17952535	26.359	26.5333	0.65691037
245.23	25.544	26.5333	3.72852227	25.952	26.5333	2.1908319	26.36	26.5333	0.65314152
258.8	26.393	26.5333	0.52876951	26.475	26.5333	0.21972389	26.55	26.5333	-0.0629398
270	26.394	26.5333	0.52500066	26.476	26.5333	0.21595505	26.552	26.5333	-0.0704775
281.2	26.393	26.5333	0.52876951	26.475	26.5333	0.21972389	26.55	26.5333	-0.0629398
294.77	25.544	26.5333	3.72852227	25.952	26.5333	2.1908319	26.36	26.5333	0.65314152
299.97	25.552	26.5333	3.69837148	25.955	26.5333	2.17952535	26.359	26.5333	0.65691037
323.54	25.611	26.5333	3.47600939	25.98	26.5333	2.08530413	26.35	26.5333	0.69083001
343.57	25.678	26.5333	3.22349651	26.012	26.5333	1.96470096	26.345	26.5333	0.70967426

Table C.4 Comparison of τ_{xy} along the mid cross-section of the tube for layer 4, 5, 6 and stacking sequence is $[0]_{6T}$ between FEM and CLPT with $\frac{b}{a} = 0.8$

	SXYLAYER 4			**SXYLAYER 5**			**SXYLAYER 6**		
ANGLE (deg)	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**
0	26.536	26.5333	-0.0101759	26.578	26.5333	-0.1684675	26.61	26.5333	-0.2890707
16.432	26.679	26.5333	-0.5491213	27.013	26.5333	-1.8079168	27.347	26.5333	-3.0667124
34.46	26.72	26.5333	-0.7036441	27.089	26.5333	-2.0943494	27.459	26.5333	-3.4888235
60.03	26.762	26.5333	-0.8619358	27.166	26.5333	-2.3845507	27.569	26.5333	-3.9033969
65.23	26.769	26.5333	-0.8883177	27.177	26.5333	-2.4260081	27.586	26.5333	-3.9674673
78.8	26.619	26.5333	-0.3229904	26.682	26.5333	-0.5604278	26.739	26.5333	-0.7752522
90	26.621	26.5333	-0.3305281	26.685	26.5333	-0.5717344	26.743	26.5333	-0.7903276
101.2	26.619	26.5333	-0.3229904	26.682	26.5333	-0.5604278	26.739	26.5333	-0.7752522
114.77	26.769	26.5333	-0.8883177	27.177	26.5333	-2.4260081	27.586	26.5333	-3.9674673

Table C.4 – *Continued*

119.97	26.762	26.5333	-0.8619358	27.166	26.5333	-2.3845507	27.569	26.5333	-3.9033969
143.54	26.72	26.5333	-0.7036441	27.089	26.5333	-2.0943494	27.459	26.5333	-3.4888235
163.57	26.679	26.5333	-0.5491213	27.013	26.5333	-1.8079168	27.347	26.5333	-3.0667124
180	26.536	26.5333	-0.0101759	26.578	26.5333	-0.1684675	26.61	26.5333	-0.2890707
196.43	26.679	26.5333	-0.5491213	27.013	26.5333	-1.8079168	27.347	26.5333	-3.0667124
216.46	26.72	26.5333	-0.7036441	27.089	26.5333	-2.0943494	27.459	26.5333	-3.4888235
240.03	26.762	26.5333	-0.8619358	27.166	26.5333	-2.3845507	27.569	26.5333	-3.9033969
245.23	26.769	26.5333	-0.8883177	27.177	26.5333	-2.4260081	27.586	26.5333	-3.9674673
258.8	26.619	26.5333	-0.3229904	26.682	26.5333	-0.5604278	26.739	26.5333	-0.7752522
270	26.621	26.5333	-0.3305281	26.685	26.5333	-0.5717344	26.743	26.5333	-0.7903276
281.2	26.619	26.5333	-0.3229904	26.682	26.5333	-0.5604278	26.739	26.5333	-0.7752522
294.77	26.769	26.5333	-0.8883177	27.177	26.5333	-2.4260081	27.586	26.5333	-3.9674673
299.97	26.762	26.5333	-0.8619358	27.166	26.5333	-2.3845507	27.569	26.5333	-3.9033969
323.54	26.72	26.5333	-0.7036441	27.089	26.5333	-2.0943494	27.459	26.5333	-3.4888235
343.57	26.679	26.5333	-0.5491213	27.013	26.5333	-1.8079168	27.347	26.5333	-3.0667124

Table C.5 Comparison of τ_{xy} along the mid cross-section of the tube for layer 1, 2, 3 and stacking sequence is $[0]_{6T}$ between FEM and CLPT with $\frac{b}{a} = 0.6$

	SXYLAYER 1			**SXYLAYER 2**			**SXYLAYER 3**		
ANGLE (deg)	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**
0	35.136	35.3667	0.65230853	35.222	35.3667	0.40914193	35.292	35.3667	0.21121564
12.46	34.331	35.3667	2.92846095	34.732	35.3667	1.79462602	35.132	35.3667	0.6636186
28.98	34.061	35.3667	3.69189096	34.585	35.3667	2.21027124	35.108	35.3667	0.73147905
44.16	33.858	35.3667	4.26587722	34.482	35.3667	2.50150565	35.106	35.3667	0.73713408
58.38	33.833	35.3667	4.33656519	34.471	35.3667	2.53260836	35.108	35.3667	0.73147905

Table C.5 – *Continued*

75.21	35.163	35.3667	0.57596553	35.288	35.3667	0.22252571	35.406	35.3667	-0.1111215
90	35.163	35.3667	0.57596553	35.29	35.3667	0.21687067	35.409	35.3667	-0.119604
104.79	35.163	35.3667	0.57596553	35.288	35.3667	0.22252571	35.406	35.3667	-0.1111215
121.62	33.833	35.3667	4.33656519	34.471	35.3667	2.53260836	35.108	35.3667	0.73147905
135.84	33.858	35.3667	4.26587722	34.482	35.3667	2.50150565	35.106	35.3667	0.73713408
151.02	34.061	35.3667	3.69189096	34.585	35.3667	2.21027124	35.108	35.3667	0.73147905
167.54	34.331	35.3667	2.92846095	34.732	35.3667	1.79462602	35.132	35.3667	0.6636186
180	35.136	35.3667	0.65230853	35.222	35.3667	0.40914193	35.292	35.3667	0.21121564
192.46	34.331	35.3667	2.92846095	34.732	35.3667	1.79462602	35.132	35.3667	0.6636186
208.98	34.061	35.3667	3.69189096	34.585	35.3667	2.21027124	35.108	35.3667	0.73147905
224.16	33.858	35.3667	4.26587722	34.482	35.3667	2.50150565	35.106	35.3667	0.73713408
238.38	33.833	35.3667	4.33656519	34.471	35.3667	2.53260836	35.108	35.3667	0.73147905
255.21	35.163	35.3667	0.57596553	35.288	35.3667	0.22252571	35.406	35.3667	-0.1111215
270	35.163	35.3667	0.57596553	35.29	35.3667	0.21687067	35.409	35.3667	-0.119604
284.79	35.163	35.3667	0.57596553	35.288	35.3667	0.22252571	35.406	35.3667	-0.1111215
301.62	33.833	35.3667	4.33656519	34.471	35.3667	2.53260836	35.108	35.3667	0.73147905
315.84	33.858	35.3667	4.26587722	34.482	35.3667	2.50150565	35.106	35.3667	0.73713408
331.02	34.061	35.3667	3.69189096	34.585	35.3667	2.21027124	35.108	35.3667	0.73147905
347.54	34.331	35.3667	2.92846095	34.732	35.3667	1.79462602	35.132	35.3667	0.6636186

Table C.6 Comparison of τ_{xy} along the mid cross-section of the tube for layer 4, 5, 6 and stacking sequence is $[0]_{6T}$ between FEM and CLPT with $\frac{b}{a} = 0.6$

	SXYLAYER 4			**SXYLAYER 5**			**SXYLAYER 6**		
ANGLE (deg)	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**
0	35.344	35.3667	0.06418467	35.381	35.3667	-0.0404335	35.398	35.3667	-0.0885013

Table C.6 – *Continued*

12.46	35.532	35.3667	-0.4673888	35.933	35.3667	-1.6012238	36.333	35.3667	-2.7322312
28.98	35.632	35.3667	-0.7501407	36.155	35.3667	-2.2289329	36.679	35.3667	-3.7105526
44.16	35.73	35.3667	-1.0272375	36.354	35.3667	-2.7916091	36.978	35.3667	-4.5559806
58.38	35.745	35.3667	-1.0696503	36.382	35.3667	-2.8707796	37.019	35.3667	-4.6719089
75.21	35.517	35.3667	-0.424976	35.62	35.3667	-0.7162104	35.716	35.3667	-0.9876522
90	35.521	35.3667	-0.4362861	35.626	35.3667	-0.7331756	35.724	35.3667	-1.0102724
104.79	35.517	35.3667	-0.424976	35.62	35.3667	-0.7162104	35.716	35.3667	-0.9876522
121.62	35.745	35.3667	-1.0696503	36.382	35.3667	-2.8707796	37.019	35.3667	-4.6719089
135.84	35.73	35.3667	-1.0272375	36.354	35.3667	-2.7916091	36.978	35.3667	-4.5559806
151.02	35.632	35.3667	-0.7501407	36.155	35.3667	-2.2289329	36.679	35.3667	-3.7105526
167.54	35.532	35.3667	-0.4673888	35.933	35.3667	-1.6012238	36.333	35.3667	-2.7322312
180	35.344	35.3667	0.06418467	35.379	35.3667	-0.0347785	35.398	35.3667	-0.0885013
192.46	35.532	35.3667	-0.4673888	35.933	35.3667	-1.6012238	36.333	35.3667	-2.7322312
208.98	35.632	35.3667	-0.7501407	36.155	35.3667	-2.2289329	36.679	35.3667	-3.7105526
224.16	35.73	35.3667	-1.0272375	36.354	35.3667	-2.7916091	36.978	35.3667	-4.5559806
238.38	35.745	35.3667	-1.0696503	36.382	35.3667	-2.8707796	37.019	35.3667	-4.6719089
255.21	35.517	35.3667	-0.424976	35.62	35.3667	-0.7162104	35.716	35.3667	-0.9876522
270	35.521	35.3667	-0.4362861	35.626	35.3667	-0.7331756	35.724	35.3667	-1.0102724
284.79	35.517	35.3667	-0.424976	35.62	35.3667	-0.7162104	35.716	35.3667	-0.9876522
301.62	35.745	35.3667	-1.0696503	36.382	35.3667	-2.8707796	37.019	35.3667	-4.6719089
315.84	35.73	35.3667	-1.0272375	36.354	35.3667	-2.7916091	36.978	35.3667	-4.5559806
331.02	35.632	35.3667	-0.7501407	36.155	35.3667	-2.2289329	36.679	35.3667	-3.7105526
347.54	35.532	35.3667	-0.4673888	35.933	35.3667	-1.6012238	36.333	35.3667	-2.7322312

Table C.7 Comparison of τ_{xy} along the mid cross-section of the tube for layer 1, 2, 3 and stacking sequence is $[0]_{6T}$ between FEM and CLPT with $\frac{b}{a} = 0.4$

	SXYLAYER 1			SXYLAYER 2			SXYLAYER 3		
ANGLE (deg)	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)3**	**Analytical Result (lb-in)4**	**Miss Match (%)**
0	52.676	53.0667	0.73624326	52.809	53.0667	0.48561527	52.902	53.0667	0.31036413
8.35	51.646	53.0667	2.67719681	52.194	53.0667	1.64453414	52.743	53.0667	0.60998705
20.25	50.671	53.0667	4.51450721	51.616	53.0667	2.73372944	52.562	53.0667	0.95106724
40.9	50.369	53.0667	5.08360233	51.206	53.0667	3.50634202	52.443	53.0667	1.17531333
47.27	50.284	53.0667	5.24377811	51.157	53.0667	3.59867864	52.43	53.0667	1.1998108
68.4	52.505	53.0667	1.05847923	52.755	53.0667	0.587374	52.996	53.0667	0.13322856
90	52.497	53.0667	1.0735546	52.751	53.0667	0.59491169	52.995	53.0667	0.13511298
111.6	52.505	53.0667	1.05847923	52.755	53.0667	0.587374	52.996	53.0667	0.13322856
132.73	50.284	53.0667	5.24377811	51.157	53.0667	3.59867864	52.43	53.0667	1.1998108
139.1	50.369	53.0667	5.08360233	51.206	53.0667	3.50634202	52.443	53.0667	1.17531333
159.75	50.671	53.0667	4.51450721	51.616	53.0667	2.73372944	52.562	53.0667	0.95106724
171.65	51.646	53.0667	2.67719681	52.194	53.0667	1.64453414	52.743	53.0667	0.60998705
180	52.676	53.0667	0.73624326	52.809	53.0667	0.48561527	52.902	53.0667	0.31036413
188.35	51.646	53.0667	2.67719681	52.194	53.0667	1.64453414	52.743	53.0667	0.60998705
200.25	50.671	53.0667	4.51450721	51.616	53.0667	2.73372944	52.562	53.0667	0.95106724
220.9	50.369	53.0667	5.08360233	51.206	53.0667	3.50634202	52.443	53.0667	1.17531333
227.27	50.284	53.0667	5.24377811	51.157	53.0667	3.59867864	52.43	53.0667	1.1998108
248.4	52.505	53.0667	1.05847923	52.755	53.0667	0.587374	52.996	53.0667	0.13322856
270	52.497	53.0667	1.0735546	52.751	53.0667	0.59491169	52.995	53.0667	0.13511298
291.6	52.505	53.0667	1.05847923	52.755	53.0667	0.587374	52.996	53.0667	0.13322856
312.73	50.284	53.0667	5.24377811	51.157	53.0667	3.59867864	52.43	53.0667	1.1998108

Table C.7 – *Continued*

319.1	50.369	53.0667	5.08360233	51.206	53.0667	3.50634202	52.443	53.0667	1.17531333
339.75	50.671	53.0667	4.51450721	51.616	53.0667	2.73372944	52.562	53.0667	0.95106724
351.65	51.646	53.0667	2.67719681	52.194	53.0667	1.64453414	52.743	53.0667	0.60998705

Table C.8 Comparison of τ_{xy} along the mid cross-section of the tube for layer 4, 5, 6 and stacking sequence is $[0]_{6T}$ between FEM and CLPT with $\frac{b}{a} = 0.4$

	SXYLAYER 4			SXYLAYER 5			SXYLAYER 6		
ANGLE (deg)	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**
0	52.955	53.0667	0.21048982	52.968	53.0667	0.18599235	52.942	53.0667	0.23498729
8.35	53.292	53.0667	-0.42456	53.84	53.0667	-1.4572227	54.389	53.0667	-2.4917698
20.25	53.507	53.0667	-0.8297105	54.452	53.0667	-2.6104883	55.398	53.0667	-4.3931505
40.9	53.68	53.0667	-1.1557154	54.917	53.0667	-3.486744	56.014	53.0667	-5.5539538
47.27	53.703	53.0667	-1.199057	54.976	53.0667	-3.5979249	56.049	53.0667	-5.6199085
68.4	53.226	53.0667	-0.3001883	53.446	53.0667	-0.7147609	53.657	53.0667	-1.1123737
90	53.23	53.0667	-0.3077259	53.455	53.0667	-0.7317206	53.67	53.0667	-1.1368711
111.6	53.226	53.0667	-0.3001883	53.446	53.0667	-0.7147609	53.657	53.0667	-1.1123737
132.73	53.703	53.0667	-1.199057	54.976	53.0667	-3.5979249	56.049	53.0667	-5.6199085
139.1	53.68	53.0667	-1.1557154	54.917	53.0667	-3.486744	56.014	53.0667	-5.5539538
159.75	53.507	53.0667	-0.8297105	54.452	53.0667	-2.6104883	55.398	53.0667	-4.3931505
171.65	53.292	53.0667	-0.42456	53.84	53.0667	-1.4572227	54.389	53.0667	-2.4917698
180	52.955	53.0667	0.21048982	52.968	53.0667	0.18599235	52.942	53.0667	0.23498729
188.35	53.292	53.0667	-0.42456	53.84	53.0667	-1.4572227	54.389	53.0667	-2.4917698
200.25	53.507	53.0667	-0.8297105	54.452	53.0667	-2.6104883	55.398	53.0667	-4.3931505
220.9	53.68	53.0667	-1.1557154	54.917	53.0667	-3.486744	56.014	53.0667	-5.5539538
227.27	53.703	53.0667	-1.199057	54.976	53.0667	-3.5979249	56.049	53.0667	-5.6199085

Table C.8 – *Continued*

248.4	53.226	53.0667	-0.300188	53.446	53.0667	-0.714760	53.657	53.0667	-1.1123737
270	53.23	53.0667	-0.307725	53.455	53.0667	-0.731720	53.67	53.0667	-1.1368711
291.6	53.226	53.0667	-0.300188	53.446	53.0667	-0.714760	53.657	53.0667	-1.1123737
312.73	53.703	53.0667	-1.199057	54.976	53.0667	-3.597924	56.049	53.0667	-5.6199085
319.1	53.68	53.0667	-1.155715	54.917	53.0667	-3.486744	56.014	53.0667	-5.5539538
339.75	53.507	53.0667	-0.829710	54.452	53.0667	-2.610488	55.398	53.0667	-4.3931505
351.65	53.292	53.0667	-0.42456	53.84	53.0667	-1.457222	54.389	53.0667	-2.4917698

Table C.9 Comparison of τ_{xy} along the mid cross-section of the tube for layer 1, 2, 3 and stacking sequence is $[0]_{6T}$ between FEM and CLPT with $\frac{b}{a} = 0.2$

	SXYLAYER 1			**SXYLAYER 2**			**SXYLAYER 3**		
ANGLE (deg)	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**
0	103.86	106.103	2.11426035	104.23	106.103	1.76554358	104.44	106.103	1.56762325
4.18	102.61	106.103	3.29235754	103.88	106.103	2.09541079	105.15	106.103	0.89846404
10.44	98.937	106.103	6.75407834	101.07	106.103	4.74377329	104.21	106.103	1.78439313
23.41	97.584	106.103	8.02925074	100.063	106.103	5.69284838	103.54	106.103	2.41585323
28.42	97.175	106.103	8.41472414	99.817	106.103	5.92469791	103.46	106.103	2.49125145
51.62	103.37	106.103	2.57607445	104.38	106.103	1.62417192	105.37	106.103	0.69111894
90	103.3	106.103	2.64204789	104.33	106.103	1.6712958	105.35	106.103	0.70996849
128.38	103.37	106.103	2.57607445	104.38	106.103	1.62417192	105.37	106.103	0.69111894
151.58	97.175	106.103	8.41472414	99.817	106.103	5.92469791	103.46	106.103	2.49125145
156.59	97.584	106.103	8.02925074	100.063	106.103	5.69284838	103.54	106.103	2.41585323
169.56	98.937	106.103	6.75407834	101.07	106.103	4.74377329	104.21	106.103	1.78439313
177.59	102.61	106.103	3.29235754	103.88	106.103	2.09541079	105.15	106.103	0.89846404
180	103.86	106.103	2.11426035	104.23	106.103	1.76554358	104.44	106.103	1.56762325

Table C.9 – *Continued*

184.18	102.61	106.103	3.29235754	103.88	106.103	2.09541079	105.15	106.103	0.89846404
190.44	98.937	106.103	6.75407834	101.07	106.103	4.74377329	104.21	106.103	1.78439313
203.41	97.584	106.103	8.02925074	100.063	106.103	5.69284838	103.54	106.103	2.41585323
208.42	97.175	106.103	8.41472414	99.817	106.103	5.92469791	103.46	106.103	2.49125145
231.62	103.37	106.103	2.57607445	104.38	106.103	1.62417192	105.37	106.103	0.69111894
270	103.3	106.103	2.64204789	104.33	106.103	1.6712958	105.35	106.103	0.70996849
308.38	103.37	106.103	2.57607445	104.38	106.103	1.62417192	105.37	106.103	0.69111894
331.58	97.175	106.103	8.41472414	99.817	106.103	5.92469791	103.46	106.103	2.49125145
336.59	97.584	106.103	8.02925074	100.063	106.103	5.69284838	103.54	106.103	2.41585323
349.56	98.937	106.103	6.75407834	101.07	106.103	4.74377329	104.21	106.103	1.78439313
355.82	102.61	106.103	3.29235754	103.88	106.103	2.09541079	105.15	106.103	0.89846404

Table C.10 Comparison of τ_{xy} along the mid cross-section of the tube for layer 4, 5, 6 and stacking sequence is $[0]_{6T}$ between FEM and CLPT with $\frac{b}{a} = 0.2$

	SXYLAYER 4			**SXYLAYER 5**			**SXYLAYER 6**		
ANGLE (deg)	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**
0	104.5	106.103	1.51107458	104.39	106.103	1.61474714	104.13	106.103	1.85979135
4.18	106.42	106.103	-0.2984827	107.69	106.103	-1.4954295	108.96	106.103	-2.6923762
10.44	107.35	106.103	-1.174987	110.49	106.103	-4.1343672	113.63	106.103	-7.0937473
23.41	108.02	106.103	-1.8064471	112.5	106.103	-6.0287475	114.98	106.103	-8.3660923
28.42	108.1	106.103	-1.8818453	112.75	106.103	-6.2643669	115.39	106.103	-8.7525082
51.62	106.34	106.103	-0.2230845	107.29	106.103	-1.1184384	108.23	106.103	-2.0043674
90	106.35	106.103	-0.2325093	107.33	106.103	-1.1561375	108.3	106.103	-2.0703409
128.38	106.34	106.103	-0.2230845	107.29	106.103	-1.1184384	108.23	106.103	-2.0043674
151.58	108.1	106.103	-1.8818453	112.75	106.103	-6.2643669	115.39	106.103	-8.7525082

Table C.10 - *Continued*

156.59	108.02	106.103	-1.8064471	112.5	106.103	-6.0287475	114.98	106.103	-8.3660923
169.56	107.35	106.103	-1.174987	110.49	106.103	-4.1343672	113.63	106.103	-7.0937473
177.59	106.42	106.103	-0.2984827	107.69	106.103	-1.4954295	108.96	106.103	-2.6923762
180	104.5	106.103	1.51107458	104.39	106.103	1.61474714	104.13	106.103	1.85979135
184.18	106.42	106.103	-0.2984827	107.69	106.103	-1.4954295	108.96	106.103	-2.6923762
190.44	107.35	106.103	-1.174987	110.49	106.103	-4.1343672	113.63	106.103	-7.0937473
203.41	108.02	106.103	-1.8064471	112.5	106.103	-6.0287475	114.98	106.103	-8.3660923
208.42	108.1	106.103	-1.8818453	112.75	106.103	-6.2643669	115.39	106.103	-8.7525082
231.62	106.34	106.103	-0.2230845	107.29	106.103	-1.1184384	108.23	106.103	-2.0043674
270	106.35	106.103	-0.2325093	107.33	106.103	-1.1561375	108.3	106.103	-2.0703409
308.38	106.34	106.103	-0.2230845	107.29	106.103	-1.1184384	108.23	106.103	-2.0043674
331.58	108.1	106.103	-1.8818453	112.75	106.103	-6.2643669	115.39	106.103	-8.7525082
336.59	108.02	106.103	-1.8064471	112.5	106.103	-6.0287475	114.98	106.103	-8.3660923
349.56	107.35	106.103	-1.174987	110.49	106.103	-4.1343672	113.63	106.103	-7.0937473
355.82	106.42	106.103	-0.2984827	107.69	106.103	-1.4954295	108.96	106.103	-2.6923762

Table C.11 Comparison of τ_{xy} along the mid cross-section of the tube for layer 1, 2, 3 and stacking sequence is $[45]_{6T}$ between FEM and CLPT with $\frac{b}{a} = 1$

	SXYLAYER 1			**SXYLAYER 2**			**SXYLAYER 3**		
ANGLE (deg)	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**
0	21.052	21.2333	0.85384749	21.135	21.2333	0.46295206	21.21	21.2333	0.1097333
20.25	20.863	21.2333	1.74395878	20.989	21.2333	1.15055126	21.115	21.2333	0.55714373
42.75	20.863	21.2333	1.74395878	20.989	21.2333	1.15055126	21.115	21.2333	0.55714373
65.25	20.863	21.2333	1.74395878	20.989	21.2333	1.15055126	21.115	21.2333	0.55714373
69.75	20.863	21.2333	1.74395878	20.989	21.2333	1.15055126	21.115	21.2333	0.55714373

Table C.11 – *Continued*

81	21.052	21.2333	0.85384749	21.135	21.2333	0.46295206	21.21	21.2333	0.1097333
90	21.052	21.2333	0.85384749	21.135	21.2333	0.46295206	21.21	21.2333	0.1097333
99	21.052	21.2333	0.85384749	21.135	21.2333	0.46295206	21.21	21.2333	0.1097333
110.25	20.863	21.2333	1.74395878	20.989	21.2333	1.15055126	21.115	21.2333	0.55714373
137.25	20.863	21.2333	1.74395878	20.989	21.2333	1.15055126	21.115	21.2333	0.55714373
155.75	20.863	21.2333	1.74395878	20.989	21.2333	1.15055126	21.115	21.2333	0.55714373
159.75	20.863	21.2333	1.74395878	20.989	21.2333	1.15055126	21.115	21.2333	0.55714373
180	21.052	21.2333	0.85384749	21.135	21.2333	0.46295206	21.21	21.2333	0.1097333
200.25	20.863	21.2333	1.74395878	20.989	21.2333	1.15055126	21.115	21.2333	0.55714373
222.75	20.863	21.2333	1.74395878	20.989	21.2333	1.15055126	21.115	21.2333	0.55714373
245.25	20.863	21.2333	1.74395878	20.989	21.2333	1.15055126	21.115	21.2333	0.55714373
249.75	20.863	21.2333	1.74395878	20.989	21.2333	1.15055126	21.115	21.2333	0.55714373
261	21.052	21.2333	0.85384749	21.135	21.2333	0.46295206	21.21	21.2333	0.1097333
270	21.052	21.2333	0.85384749	21.135	21.2333	0.46295206	21.21	21.2333	0.1097333
279	21.052	21.2333	0.85384749	21.135	21.2333	0.46295206	21.21	21.2333	0.1097333
290.25	20.863	21.2333	1.74395878	20.989	21.2333	1.15055126	21.115	21.2333	0.55714373
294.75	20.863	21.2333	1.74395878	20.989	21.2333	1.15055126	21.115	21.2333	0.55714373
317.25	20.863	21.2333	1.74395878	20.989	21.2333	1.15055126	21.115	21.2333	0.55714373
339.75	20.863	21.2333	1.74395878	20.989	21.2333	1.15055126	21.115	21.2333	0.55714373

Table C.12 Comparison of τ_{xy} along the mid cross-section of the tube for layer 4, 5, 6 and stacking sequence is $[45]_{6T}$ between FEM and CLPT with $\frac{b}{a} = 1$

	SXYLAYER 4			SXYLAYER 5			SXYLAYER 6		
ANGLE (deg)	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**
0	21.277	21.2333	-0.2058088	21.337	21.2333	-0.4883838	21.389	21.2333	-0.7332822

Table C.12 – *Continued*

20.25	21.341	21.2333	-0.5072221	21.566	21.2333	-1.5668784	21.612	21.2333	-1.7835193
42.75	21.341	21.2333	-0.5072221	21.566	21.2333	-1.5668784	21.612	21.2333	-1.7835193
65.25	21.341	21.2333	-0.5072221	21.566	21.2333	-1.5668784	21.612	21.2333	-1.7835193
69.75	21.341	21.2333	-0.5072221	21.566	21.2333	-1.5668784	21.612	21.2333	-1.7835193
81	21.277	21.2333	-0.2058088	21.337	21.2333	-0.4883838	21.389	21.2333	-0.7332822
90	21.277	21.2333	-0.2058088	21.337	21.2333	-0.4883838	21.389	21.2333	-0.7332822
99	21.277	21.2333	-0.2058088	21.337	21.2333	-0.4883838	21.389	21.2333	-0.7332822
110.25	21.341	21.2333	-0.5072221	21.566	21.2333	-1.5668784	21.612	21.2333	-1.7835193
137.25	21.341	21.2333	-0.5072221	21.566	21.2333	-1.5668784	21.612	21.2333	-1.7835193
155.75	21.341	21.2333	-0.5072221	21.566	21.2333	-1.5668784	21.612	21.2333	-1.7835193
159.75	21.341	21.2333	-0.5072221	21.566	21.2333	-1.5668784	21.612	21.2333	-1.7835193
180	21.277	21.2333	-0.2058088	21.337	21.2333	-0.4883838	21.389	21.2333	-0.7332822
200.25	21.341	21.2333	-0.5072221	21.566	21.2333	-1.5668784	21.612	21.2333	-1.7835193
222.75	21.341	21.2333	-0.5072221	21.566	21.2333	-1.5668784	21.612	21.2333	-1.7835193
245.25	21.341	21.2333	-0.5072221	21.566	21.2333	-1.5668784	21.612	21.2333	-1.7835193
249.75	21.341	21.2333	-0.5072221	21.566	21.2333	-1.5668784	21.612	21.2333	-1.7835193
261	21.277	21.2333	-0.2058088	21.337	21.2333	-0.4883838	21.389	21.2333	-0.7332822
270	21.277	21.2333	-0.2058088	21.337	21.2333	-0.4883838	21.389	21.2333	-0.7332822
279	21.277	21.2333	-0.2058088	21.337	21.2333	-0.4883838	21.389	21.2333	-0.7332822
290.25	21.341	21.2333	-0.5072221	21.566	21.2333	-1.5668784	21.612	21.2333	-1.7835193
294.75	21.341	21.2333	-0.5072221	21.566	21.2333	-1.5668784	21.612	21.2333	-1.7835193
317.25	21.341	21.2333	-0.5072221	21.566	21.2333	-1.5668784	21.612	21.2333	-1.7835193
339.75	21.341	21.2333	-0.5072221	21.566	21.2333	-1.5668784	21.612	21.2333	-1.7835193

Table C.13 Comparison of τ_{xy} along the mid cross-section of the tube for layer 1, 2, 3 and stacking sequence is $[45]_{6T}$ between FEM and CLPT with $\frac{b}{a} = 0.8$

	SXYLAYER 1			SXYLAYER 2			SXYLAYER 3		
ANGLE (deg)	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**
0	26.443	26.5333	0.34032706	26.483	26.5333	0.1895731	26.557	26.5333	-0.0893217
16.432	25.887	26.5333	2.43580708	25.906	26.5333	2.36419895	26.344	26.5333	0.71344311
34.46	25.723	26.5333	3.05389831	25.776	26.5333	2.85414931	26.284	26.5333	0.93957404
60.03	25.548	26.5333	3.71344688	25.638	26.5333	3.37425047	26.217	26.5333	1.19208692
65.23	25.522	26.5333	3.81143695	25.616	26.5333	3.45716515	26.206	26.5333	1.23354426
78.8	26.308	26.5333	0.84912167	26.363	26.5333	0.64183498	26.469	26.5333	0.24233699
90	26.304	26.5333	0.86419707	26.36	26.5333	0.65314152	26.466	26.5333	0.25364353
101.2	26.308	26.5333	0.84912167	26.363	26.5333	0.64183498	26.469	26.5333	0.24233699
114.77	25.522	26.5333	3.81143695	25.616	26.5333	3.45716515	26.206	26.5333	1.23354426
119.97	25.548	26.5333	3.71344688	25.638	26.5333	3.37425047	26.217	26.5333	1.19208692
143.54	25.723	26.5333	3.05389831	25.776	26.5333	2.85414931	26.284	26.5333	0.93957404
163.57	25.887	26.5333	2.43580708	25.906	26.5333	2.36419895	26.344	26.5333	0.71344311
180	26.443	26.5333	0.34032706	26.483	26.5333	0.1895731	26.557	26.5333	-0.0893217
196.432	25.887	26.5333	2.43580708	25.906	26.5333	2.36419895	26.344	26.5333	0.71344311
216.46	25.723	26.5333	3.05389831	25.776	26.5333	2.85414931	26.284	26.5333	0.93957404
240.03	25.548	26.5333	3.71344688	25.638	26.5333	3.37425047	26.217	26.5333	1.19208692
245.23	25.522	26.5333	3.81143695	25.616	26.5333	3.45716515	26.206	26.5333	1.23354426
258.8	26.308	26.5333	0.84912167	26.363	26.5333	0.64183498	26.469	26.5333	0.24233699
270	26.304	26.5333	0.86419707	26.36	26.5333	0.65314152	26.466	26.5333	0.25364353
281.2	26.308	26.5333	0.84912167	26.363	26.5333	0.64183498	26.469	26.5333	0.24233699
294.77	25.522	26.5333	3.81143695	25.616	26.5333	3.45716515	26.206	26.5333	1.23354426

Table C.13 – *Continued*

299.97	25.548	26.5333	3.71344688	25.638	26.5333	3.37425047	26.217	26.5333	1.19208692
323.54	25.723	26.5333	3.05389831	25.776	26.5333	2.85414931	26.284	26.5333	0.93957404
343.57	25.887	26.5333	2.43580708	25.906	26.5333	2.36419895	26.344	26.5333	0.71344311

Table C.14 Comparison of τ_{xy} along the mid cross-section of the tube for layer 4, 5, 6 and stacking sequence is $[45]_{6T}$ between FEM and CLPT with $\frac{b}{a} = 0.8$

	SXYLAYER 4			SXYLAYER 5			SXYLAYER 6		
ANGLE (deg)	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**
0	26.62	26.5333	-0.3267592	26.672	26.5333	-0.5227394	26.712	26.5333	-0.6734933
16.432	26.783	26.5333	-0.9410816	27.221	26.5333	-2.5918374	27.459	26.5333	-3.4888235
34.46	26.791	26.5333	-0.9712324	27.298	26.5333	-2.8820388	27.505	26.5333	-3.6621905
60.03	26.796	26.5333	-0.9900766	27.375	26.5333	-3.1722402	27.554	26.5333	-3.8468641
65.23	26.796	26.5333	-0.9900766	27.386	26.5333	-3.2136975	27.576	26.5333	-3.9297788
78.8	26.565	26.5333	-0.1194725	26.653	26.5333	-0.4511312	26.732	26.5333	-0.7488703
90	26.563	26.5333	-0.1119348	26.652	26.5333	-0.4473624	26.732	26.5333	-0.7488703
101.2	26.565	26.5333	-0.1194725	26.653	26.5333	-0.4511312	26.732	26.5333	-0.7488703
114.77	26.796	26.5333	-0.9900766	27.386	26.5333	-3.2136975	27.576	26.5333	-3.9297788
119.97	26.796	26.5333	-0.9900766	27.375	26.5333	-3.1722402	27.554	26.5333	-3.8468641
143.54	26.791	26.5333	-0.9712324	27.298	26.5333	-2.8820388	27.505	26.5333	-3.6621905
163.57	26.783	26.5333	-0.9410816	27.221	26.5333	-2.5918374	27.459	26.5333	-3.4888235
180	26.62	26.5333	-0.3267592	26.672	26.5333	-0.5227394	26.512	26.5333	0.08027648
196.432	26.783	26.5333	-0.9410816	27.221	26.5333	-2.5918374	27.459	26.5333	-3.4888235
216.46	26.791	26.5333	-0.9712324	27.298	26.5333	-2.8820388	27.505	26.5333	-3.6621905
240.03	26.796	26.5333	-0.9900766	27.375	26.5333	-3.1722402	27.554	26.5333	-3.8468641
245.23	26.796	26.5333	-0.9900766	27.386	26.5333	-3.2136975	27.576	26.5333	-3.9297788

Table C.14 – *Continued*

258.8	26.565	26.5333	-0.1194725	26.653	26.5333	-0.4511312	26.732	26.5333	-0.7488703
270	26.563	26.5333	-0.1119348	26.652	26.5333	-0.4473624	26.732	26.5333	-0.7488703
281.2	26.565	26.5333	-0.1194725	26.653	26.5333	-0.4511312	26.732	26.5333	-0.7488703
294.77	26.796	26.5333	-0.9900766	27.386	26.5333	-3.2136975	27.576	26.5333	-3.9297788
299.97	26.796	26.5333	-0.9900766	27.375	26.5333	-3.1722402	27.554	26.5333	-3.8468641
323.54	26.791	26.5333	-0.9712324	27.298	26.5333	-2.8820388	27.505	26.5333	-3.6621905
343.57	26.783	26.5333	-0.9410816	27.221	26.5333	-2.5918374	27.459	26.5333	-3.4888235

Table C.15 Comparison of τ_{xy} along the mid cross-section of the tube for layer 1, 2, 3 and stacking sequence is $[45]_{6T}$ between FEM and CLPT with $\frac{b}{a} = 0.6$

	SXYLAYER 1			SXYLAYER 2			SXYLAYER 3		
ANGLE (deg)	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytica l Result (lb-in)**	**Miss Match (%)**
0	35.179	35.3667	0.53072523	35.279	35.3667	0.24797338	35.36	35.3667	0.0189443
12.46	34.562	35.3667	2.27530417	34.649	35.3667	2.02931006	35.136	35.3667	0.6523085
28.98	34.348	35.3667	2.88039314	34.337	35.3667	2.91149584	35.027	35.3667	0.9605080
44.16	34.135	35.3667	3.48265459	34.125	35.3667	3.51092977	34.915	35.3667	1.2771901
58.38	34.06	35.3667	3.69471848	34.025	35.3667	3.79368163	34.898	35.3667	1.3252579
75.21	34.971	35.3667	1.11884909	35.147	35.3667	0.62120582	35.312	35.3667	0.1546652
90	34.963	35.3667	1.14146924	35.142	35.3667	0.63534342	35.309	35.3667	0.1631478
104.79	34.971	35.3667	1.11884909	35.147	35.3667	0.62120582	35.312	35.3667	0.1546652
121.62	34.06	35.3667	3.69471848	34.025	35.3667	3.79368163	34.898	35.3667	1.3252579
135.84	34.135	35.3667	3.48265459	34.025	35.3667	3.79368163	34.915	35.3667	1.2771901
151.02	34.348	35.3667	2.88039314	34.337	35.3667	2.91149584	35.027	35.3667	0.9605080
167.54	34.562	35.3667	2.27530417	34.649	35.3667	2.02931006	35.136	35.3667	0.6523085
180	35.179	35.3667	0.53072523	35.279	35.3667	0.24797338	35.36	35.3667	0.0189443

Table C.15 – *Continued*

192.46	34.562	35.3667	2.27530417	34.649	35.3667	2.02931006	35.136	35.3667	0.65230853
208.98	34.348	35.3667	2.88039314	34.337	35.3667	2.91149584	35.027	35.3667	0.96050805
224.16	34.135	35.3667	3.48265459	34.125	35.3667	3.51092977	34.915	35.3667	1.27719013
238.38	34.06	35.3667	3.69471848	34.025	35.3667	3.79368163	34.898	35.3667	1.32525794
255.21	34.971	35.3667	1.11884909	35.147	35.3667	0.62120582	35.312	35.3667	0.15466526
270	34.963	35.3667	1.14146924	35.142	35.3667	0.63534342	35.309	35.3667	0.16314782
284.79	34.971	35.3667	1.11884909	35.147	35.3667	0.62120582	35.312	35.3667	0.15466526
301.62	34.06	35.3667	3.69471848	34.025	35.3667	3.79368163	34.898	35.3667	1.32525794
315.84	34.135	35.3667	3.48265459	34.125	35.3667	3.51092977	34.915	35.3667	1.27719013
331.02	34.348	35.3667	2.88039314	34.337	35.3667	2.91149584	35.027	35.3667	0.96050805
347.54	34.562	35.3667	2.27530417	34.649	35.3667	2.02931006	35.136	35.3667	0.65230853

Table C.16 Comparison of τ_{xy} along the mid cross-section of the tube for layer 4, 5, 6 and stacking sequence is $[45]_{6T}$ between FEM and CLPT with $\frac{b}{a} = 0.6$

	SXYLAYER 4			**SXYLAYER 5**			**SXYLAYER 6**		
ANGLE (deg)	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**
0	35.421	35.3667	-0.1535343	35.462	35.3667	-0.2694625	35.483	35.3667	-0.3288404
12.46	35.623	35.3667	-0.724693	36.109	35.3667	-2.098867	36.596	35.3667	-3.4758685
28.98	35.716	35.3667	-0.9876522	36.405	35.3667	-2.9358125	36.694	35.3667	-3.7529654
44.16	35.805	35.3667	-1.2393014	36.694	35.3667	-3.7529654	36.884	35.3667	-4.2901939
58.38	35.817	35.3667	-1.2732316	36.737	35.3667	-3.8745487	36.656	35.3667	-3.6455197
75.21	35.467	35.3667	-0.2836001	35.611	35.3667	-0.6907628	35.744	35.3667	-1.0668227
90	35.467	35.3667	-0.2836001	35.614	35.3667	-0.6992453	35.75	35.3667	-1.0837879
104.79	35.467	35.3667	-0.2836001	35.611	35.3667	-0.6907628	35.744	35.3667	-1.0668227
121.62	35.817	35.3667	-1.2732316	36.737	35.3667	-3.8745487	36.656	35.3667	-3.6455197

Table C.16 – *Continued*

135.84	35.805	35.3667	-1.2393014	36.694	35.3667	-3.7529654	36.884	35.3667	-4.2901939
151.02	35.716	35.3667	-0.9876522	36.405	35.3667	-2.9358125	36.694	35.3667	-3.7529654
167.54	35.623	35.3667	-0.724693	36.109	35.3667	-2.098867	36.596	35.3667	-3.4758685
180	35.421	35.3667	-0.1535343	35.462	35.3667	-0.2694625	35.483	35.3667	-0.3288404
192.46	35.623	35.3667	-0.724693	36.109	35.3667	-2.098867	36.596	35.3667	-3.4758685
208.98	35.716	35.3667	-0.9876522	36.405	35.3667	-2.9358125	36.694	35.3667	-3.7529654
224.16	35.805	35.3667	-1.2393014	36.694	35.3667	-3.7529654	36.884	35.3667	-4.2901939
238.38	35.817	35.3667	-1.2732316	36.737	35.3667	-3.8745487	36.656	35.3667	-3.6455197
255.21	35.467	35.3667	-0.2836001	35.611	35.3667	-0.6907628	35.744	35.3667	-1.0668227
270	35.467	35.3667	-0.2836001	35.614	35.3667	-0.6992453	35.75	35.3667	-1.0837879
284.79	35.467	35.3667	-0.2836001	35.611	35.3667	-0.6907628	35.744	35.3667	-1.0668227
301.62	35.817	35.3667	-1.2732316	36.737	35.3667	-3.8745487	36.656	35.3667	-3.6455197
315.84	35.805	35.3667	-1.2393014	36.694	35.3667	-3.7529654	36.884	35.3667	-4.2901939
331.02	35.716	35.3667	-0.9876522	36.405	35.3667	-2.9358125	36.694	35.3667	-3.7529654
347.54	35.623	35.3667	-0.724693	36.109	35.3667	-2.098867	36.596	35.3667	-3.4758685

Table C.17 Comparison of τ_{xy} along the mid cross-section of the tube for layer 1, 2, 3 and stacking sequence is $[45]_{6T}$ between FEM and CLPT with $\frac{b}{a} = 0.4$

	SXYLAYER 1			SXYLAYER 2			SXYLAYER 3		
ANGLE (deg)	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**
0	52.529	53.0667	1.01325313	52.682	53.0667	0.72493673	52.789	53.0667	0.52330369
8.35	51.267	53.0667	3.39139234	51.921	53.0667	2.15898106	52.574	53.0667	0.92845419
20.25	50.957	53.0667	3.97556283	51.17	53.0667	3.57418117	52.383	53.0667	1.28837859
40.9	50.234	53.0667	5.33799916	50.562	53.0667	4.7199091	52.265	53.0667	1.51074026
47.27	50.034	53.0667	5.71488334	50.483	53.0667	4.86877835	52.253	53.0667	1.53335331

Table C.17 – *Continued*

68.4	52.429	53.0667	1.20169523	52.76	53.0667	0.5779519	53.078	53.0667	-0.021294
90	52.423	53.0667	1.21300175	52.76	53.0667	0.5779519	53.084	53.0667	-0.0326005
111.6	52.429	53.0667	1.20169523	52.76	53.0667	0.5779519	53.078	53.0667	-0.021294
132.73	50.034	53.0667	5.71488334	50.483	53.0667	4.86877835	52.253	53.0667	1.53335331
139.1	50.234	53.0667	5.33799916	50.562	53.0667	4.7199091	52.265	53.0667	1.51074026
159.75	50.957	53.0667	3.97556283	51.17	53.0667	3.57418117	52.383	53.0667	1.28837859
171.65	51.267	53.0667	3.39139234	51.921	53.0667	2.15898106	52.574	53.0667	0.92845419
180	52.529	53.0667	1.01325313	52.682	53.0667	0.72493673	52.789	53.0667	0.52330369
188.35	51.267	53.0667	3.39139234	51.921	53.0667	2.15898106	52.574	53.0667	0.92845419
200.25	50.957	53.0667	3.97556283	51.17	53.0667	3.57418117	52.383	53.0667	1.28837859
220.9	50.234	53.0667	5.33799916	50.562	53.0667	4.7199091	52.265	53.0667	1.51074026
227.27	50.034	53.0667	5.71488334	50.483	53.0667	4.86877835	52.253	53.0667	1.53335331
248.4	52.429	53.0667	1.20169523	52.76	53.0667	0.5779519	53.078	53.0667	-0.021294
270	52.423	53.0667	1.21300175	52.76	53.0667	0.5779519	53.084	53.0667	-0.0326005
291.6	52.429	53.0667	1.20169523	52.76	53.0667	0.5779519	53.078	53.0667	-0.021294
312.73	50.034	53.0667	5.71488334	50.483	53.0667	4.86877835	52.253	53.0667	1.53335331
319.1	50.234	53.0667	5.33799916	50.562	53.0667	4.7199091	52.265	53.0667	1.51074026
339.75	49.957	53.0667	5.85998376	51.17	53.0667	3.57418117	52.383	53.0667	1.28837859
351.65	51.267	53.0667	3.39139234	51.921	53.0667	2.15898106	52.574	53.0667	0.92845419

Table C.18 Comparison of τ_{xy} along the mid cross-section of the tube for layer 4, 5, 6 and stacking sequence is $[45]_{6T}$ between FEM and CLPT with $\frac{b}{a} = 0.4$

	SXYLAYER 4			**SXYLAYER 5**			**SXYLAYER 6**		
ANGLE (deg)	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**
0	52.85	53.0667	0.40835401	52.866	53.0667	0.37820328	52.836	53.0667	0.43473591

Table C.18 – *Continued*

8.35	53.228	53.0667	-0.3039571	53.882	53.0667	-1.5363684	54.535	53.0667	-2.7668952
20.25	53.596	53.0667	-0.997424	54.809	53.0667	-3.2832266	56.022	53.0667	-5.5690292
40.9	53.968	53.0667	-1.6984286	55.671	53.0667	-4.9075974	56.374	53.0667	-6.2323453
47.27	54.024	53.0667	-1.8039562	55.794	53.0667	-5.1393812	56.565	53.0667	-6.5922697
68.4	53.382	53.0667	-0.5941579	53.672	53.0667	-1.14064	53.948	53.0667	-1.6607402
90	53.395	53.0667	-0.6186554	53.692	53.0667	-1.1783284	53.975	53.0667	-1.7116195
111.6	53.382	53.0667	-0.5941579	53.672	53.0667	-1.14064	53.948	53.0667	-1.6607402
132.73	54.024	53.0667	-1.8039562	55.794	53.0667	-5.1393812	56.565	53.0667	-6.5922697
139.1	53.968	53.0667	-1.6984286	55.671	53.0667	-4.9075974	56.374	53.0667	-6.2323453
159.75	53.596	53.0667	-0.997424	54.809	53.0667	-3.2832266	56.022	53.0667	-5.5690292
171.65	53.228	53.0667	-0.3039571	53.882	53.0667	-1.5363684	54.535	53.0667	-2.7668952
180	52.85	53.0667	0.40835401	52.866	53.0667	0.37820328	52.836	53.0667	0.43473591
188.35	53.228	53.0667	-0.3039571	53.882	53.0667	-1.5363684	54.535	53.0667	-2.7668952
200.25	53.596	53.0667	-0.997424	54.809	53.0667	-3.2832266	56.022	53.0667	-5.5690292
220.9	53.968	53.0667	-1.6984286	55.671	53.0667	-4.9075974	56.374	53.0667	-6.2323453
227.27	54.024	53.0667	-1.8039562	55.794	53.0667	-5.1393812	56.565	53.0667	-6.5922697
248.4	53.382	53.0667	-0.5941579	53.672	53.0667	-1.14064	53.948	53.0667	-1.6607402
270	53.395	53.0667	-0.6186554	53.692	53.0667	-1.1783284	53.975	53.0667	-1.7116195
291.6	53.382	53.0667	-0.5941579	53.672	53.0667	-1.14064	53.948	53.0667	-1.6607402
312.73	54.024	53.0667	-1.8039562	55.794	53.0667	-5.1393812	56.565	53.0667	-6.5922697
319.1	53.968	53.0667	-1.6984286	55.671	53.0667	-4.9075974	56.374	53.0667	-6.2323453
339.75	53.596	53.0667	-0.997424	54.809	53.0667	-3.2832266	56.022	53.0667	-5.5690292
351.65	53.228	53.0667	-0.3039571	53.882	53.0667	-1.5363684	54.535	53.0667	-2.7668952

Table C.19 Comparison of τ_{xy} along the mid cross-section of the tube for layer 1, 2, 3 and stacking sequence is $[45]_{6T}$ between FEM and CLPT with $\frac{b}{a} = 0.2$

	SXYLAYER 1			SXYLAYER 2			SXYLAYER 3		
ANGLE (deg)	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**
0	103.47	106.103	2.48182667	103.9	106.103	2.07656124	104.14	106.103	1.85036658
4.18	101.64	106.103	4.20656096	103.15	106.103	2.78341955	104.66	106.103	1.36027814
10.44	99.661	106.103	6.07172444	101.631	106.103	4.21504326	103.6	106.103	2.35930456
23.41	96.066	106.103	9.45993197	100.989	106.103	4.82011398	102.91	106.103	3.00961422
28.42	97.483	106.103	8.12444099	100.659	106.103	5.13113164	102.84	106.103	3.07558766
51.62	103.2	106.103	2.73629567	104.38	106.103	1.62417192	105.54	106.103	0.53089772
90	103.14	106.103	2.79284433	104.36	106.103	1.64302147	105.55	106.103	0.52147294
128.38	103.2	106.103	2.73629567	104.38	106.103	1.62417192	105.54	106.103	0.53089772
151.58	97.483	106.103	8.12444099	100.659	106.103	5.13113164	102.84	106.103	3.07558766
156.59	96.066	106.103	9.45993197	100.989	106.103	4.82011398	102.91	106.103	3.00961422
169.56	99.661	106.103	6.07172444	101.631	106.103	4.21504326	103.6	106.103	2.35930456
177.59	101.64	106.103	4.20656096	103.15	106.103	2.78341955	104.66	106.103	1.36027814
180	103.47	106.103	2.48182667	103.9	106.103	2.07656124	104.14	106.103	1.85036658
184.18	101.64	106.103	4.20656096	103.15	106.103	2.78341955	104.66	106.103	1.36027814
190.44	99.661	106.103	6.07172444	101.631	106.103	4.21504326	103.6	106.103	2.35930456
203.41	96.066	106.103	9.45993197	100.989	106.103	4.82011398	102.91	106.103	3.00961422
208.42	97.483	106.103	8.12444099	100.659	106.103	5.13113164	102.84	106.103	3.07558766
231.62	103.2	106.103	2.73629567	104.38	106.103	1.62417192	105.54	106.103	0.53089772
270	103.14	106.103	2.79284433	104.36	106.103	1.64302147	105.55	106.103	0.52147294
308.38	103.14	106.103	2.79284433	104.38	106.103	1.62417192	105.54	106.103	0.53089772
331.58	97.483	106.103	8.12444099	100.659	106.103	5.13113164	102.84	106.103	3.07558766

Table C.19 – *Continued*

336.59	96.066	106.103	9.45993197	100.989	106.103	4.82011398	102.91	106.103	3.00961422
349.56	99.661	106.103	6.07172444	101.631	106.103	4.21504326	103.6	106.103	2.35930456
355.82	101.64	106.103	4.20656096	103.15	106.103	2.78341955	104.66	106.103	1.36027814

Table C.20 Comparison of τ_{xy} along the mid cross-section of the tube for layer 4, 5, 6 and stacking sequence is $[45]_{6T}$ between FEM and CLPT with $\frac{b}{a} = 0.2$

	SXYLAYER 4			SXYLAYER 5			SXYLAYER 6		
ANGLE (deg)	FEM Result (lb-in)	Analytical Result (lb-in)	Miss Match (%)	FEM Result (lb-in)	Analytical Result (lb-in)	Miss Match (%)	FEM Result (lb-in)	Analytical Result (lb-in)	Miss Match (%)
0	104.2	106.103	1.79381791	104.08	106.103	1.90691524	103.78	106.103	2.18965857
4.18	106.16	106.103	-0.0534385	107.67	106.103	-1.4765799	109.18	106.103	-2.8997213
10.44	107.57	106.103	-1.3823321	109.54	106.103	-3.2390133	112.51	106.103	-6.0381722
23.41	108.83	106.103	-2.5698541	110.76	106.103	-4.3888362	114.68	106.103	-8.083349
28.42	109.01	106.103	-2.7395001	111.19	106.103	-4.7941016	115.36	106.103	-8.7242338
51.62	106.68	106.103	-0.5435269	107.8	106.103	-1.599102	108.89	106.103	-2.6264028
90	106.72	106.103	-0.581226	107.87	106.103	-1.6650755	108.99	106.103	-2.7206505
128.38	106.68	106.103	-0.5435269	107.8	106.103	-1.599102	108.89	106.103	-2.6264028
151.58	109.01	106.103	-2.7395001	111.19	106.103	-4.7941016	115.36	106.103	-8.7242338
156.59	108.83	106.103	-2.5698541	110.76	106.103	-4.3888362	114.68	106.103	-8.083349
169.56	107.57	106.103	-1.3823321	109.54	106.103	-3.2390133	112.51	106.103	-6.0381722
177.59	106.16	106.103	-0.0534385	107.67	106.103	-1.4765799	109.18	106.103	-2.8997213
180	104.2	106.103	1.79381791	104.08	106.103	1.90691524	103.78	106.103	2.18965857
184.18	106.16	106.103	-0.0534385	107.67	106.103	-1.4765799	109.18	106.103	-2.8997213
190.44	107.57	106.103	-1.3823321	109.54	106.103	-3.2390133	112.51	106.103	-6.0381722
203.41	108.83	106.103	-2.5698541	110.76	106.103	-4.3888362	114.68	106.103	-8.083349
208.42	109.01	106.103	-2.7395001	111.19	106.103	-4.7941016	115.36	106.103	-8.7242338

Table C.20 – *Continued*

231.62	106.68	106.103	-0.5435269	107.8	106.103	-1.599102	108.89	106.103	-2.6264028
270	106.72	106.103	-0.581226	107.87	106.103	-1.6650755	108.99	106.103	-2.7206505
308.38	106.68	106.103	-0.5435269	107.8	106.103	-1.599102	108.89	106.103	-2.6264028
331.58	109.01	106.103	-2.7395001	111.19	106.103	-4.7941016	115.36	106.103	-8.7242338
336.59	108.83	106.103	-2.5698541	110.76	106.103	-4.3888362	114.68	106.103	-8.083349
349.56	107.57	106.103	-1.3823321	109.54	106.103	-3.2390133	112.51	106.103	-6.0381722
355.82	106.16	106.103	-0.0534385	107.67	106.103	-1.4765799	109.18	106.103	-2.8997213

Table C.21 Comparison of τ_{xy} along the mid cross-section of the tube for layer 1, 2, 3 and stacking sequence is $[\pm45/0]_S$ between FEM and CLPT with $\frac{b}{a} = 1$

	SXYLAYER 1			**SXYLAYER 2**			**SXYLAYER 3**		
ANGLE (deg)	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**
0	21.052	21.2333	0.85384749	21.135	21.2333	0.46295206	21.21	21.2333	0.1097333
20.25	20.863	21.2333	1.74395878	20.989	21.2333	1.15055126	21.115	21.2333	0.55714373
42.75	20.863	21.2333	1.74395878	20.989	21.2333	1.15055126	21.115	21.2333	0.55714373
65.25	20.863	21.2333	1.74395878	20.989	21.2333	1.15055126	21.115	21.2333	0.55714373
69.75	20.863	21.2333	1.74395878	20.989	21.2333	1.15055126	21.115	21.2333	0.55714373
81	21.052	21.2333	0.85384749	21.135	21.2333	0.46295206	21.21	21.2333	0.1097333
90	21.052	21.2333	0.85384749	21.135	21.2333	0.46295206	21.21	21.2333	0.1097333
99	21.052	21.2333	0.85384749	21.135	21.2333	0.46295206	21.21	21.2333	0.1097333
110.25	20.863	21.2333	1.74395878	20.989	21.2333	1.15055126	21.115	21.2333	0.55714373
137.25	20.863	21.2333	1.74395878	20.989	21.2333	1.15055126	21.115	21.2333	0.55714373
155.75	20.863	21.2333	1.74395878	20.989	21.2333	1.15055126	21.115	21.2333	0.55714373
159.75	20.863	21.2333	1.74395878	20.989	21.2333	1.15055126	21.115	21.2333	0.55714373
180	21.052	21.2333	0.85384749	21.135	21.2333	0.46295206	21.21	21.2333	0.1097333

Table C.21 - *Continued*

200.25	20.863	21.2333	1.74395878	20.989	21.2333	1.15055126	21.115	21.2333	0.55714373
222.75	20.863	21.2333	1.74395878	20.989	21.2333	1.15055126	21.115	21.2333	0.55714373
245.25	20.863	21.2333	1.74395878	20.989	21.2333	1.15055126	21.115	21.2333	0.55714373
249.75	20.863	21.2333	1.74395878	20.989	21.2333	1.15055126	21.115	21.2333	0.55714373
261	21.052	21.2333	0.85384749	21.135	21.2333	0.46295206	21.21	21.2333	0.1097333
270	21.052	21.2333	0.85384749	21.135	21.2333	0.46295206	21.21	21.2333	0.1097333
279	21.052	21.2333	0.85384749	21.135	21.2333	0.46295206	21.21	21.2333	0.1097333
290.25	20.863	21.2333	1.74395878	20.989	21.2333	1.15055126	21.115	21.2333	0.55714373
294.75	20.863	21.2333	1.74395878	20.989	21.2333	1.15055126	21.115	21.2333	0.55714373
317.25	20.863	21.2333	1.74395878	20.989	21.2333	1.15055126	21.115	21.2333	0.55714373
339.75	20.863	21.2333	1.74395878	20.989	21.2333	1.15055126	21.115	21.2333	0.55714373

Table C.22 Comparison of τ_{xy} along the mid cross-section of the tube for layer 4, 5, 6 and stacking sequence is $[\pm 45/0]_S$ between FEM and CLPT with $\frac{b}{a} = 1$

	SXYLAYER 4			**SXYLAYER 5**			**SXYLAYER 6**		
ANGLE (deg)	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**
0	21.277	21.2333	-0.2058088	21.337	21.2333	-0.4883838	21.389	21.2333	-0.7332822
20.25	21.341	21.2333	-0.5072221	21.566	21.2333	-1.5668784	21.612	21.2333	-1.7835193
42.75	21.341	21.2333	-0.5072221	21.566	21.2333	-1.5668784	21.612	21.2333	-1.7835193
65.25	21.341	21.2333	-0.5072221	21.566	21.2333	-1.5668784	21.612	21.2333	-1.7835193
69.75	21.341	21.2333	-0.5072221	21.566	21.2333	-1.5668784	21.612	21.2333	-1.7835193
81	21.277	21.2333	-0.2058088	21.337	21.2333	-0.4883838	21.389	21.2333	-0.7332822
90	21.277	21.2333	-0.2058088	21.337	21.2333	-0.4883838	21.389	21.2333	-0.7332822
99	21.277	21.2333	-0.2058088	21.337	21.2333	-0.4883838	21.389	21.2333	-0.7332822
110.25	21.341	21.2333	-0.5072221	21.566	21.2333	-1.5668784	21.612	21.2333	-1.7835193

Table C.22 – *Continued*

137.25	21.341	21.2333	-0.5072221	21.566	21.2333	-1.5668784	21.612	21.2333	-1.7835193
155.75	21.341	21.2333	-0.5072221	21.566	21.2333	-1.5668784	21.612	21.2333	-1.7835193
159.75	21.341	21.2333	-0.5072221	21.566	21.2333	-1.5668784	21.612	21.2333	-1.7835193
180	21.277	21.2333	-0.2058088	21.337	21.2333	-0.4883838	21.389	21.2333	-0.7332822
200.25	21.341	21.2333	-0.5072221	21.566	21.2333	-1.5668784	21.612	21.2333	-1.7835193
222.75	21.341	21.2333	-0.5072221	21.566	21.2333	-1.5668784	21.612	21.2333	-1.7835193
245.25	21.341	21.2333	-0.5072221	21.566	21.2333	-1.5668784	21.612	21.2333	-1.7835193
249.75	21.341	21.2333	-0.5072221	21.566	21.2333	-1.5668784	21.612	21.2333	-1.7835193
261	21.277	21.2333	-0.2058088	21.337	21.2333	-0.4883838	21.389	21.2333	-0.7332822
270	21.277	21.2333	-0.2058088	21.337	21.2333	-0.4883838	21.389	21.2333	-0.7332822
279	21.277	21.2333	-0.2058088	21.337	21.2333	-0.4883838	21.389	21.2333	-0.7332822
290.25	21.341	21.2333	-0.5072221	21.566	21.2333	-1.5668784	21.612	21.2333	-1.7835193
294.75	21.341	21.2333	-0.5072221	21.566	21.2333	-1.5668784	21.612	21.2333	-1.7835193
317.25	21.341	21.2333	-0.5072221	21.566	21.2333	-1.5668784	21.612	21.2333	-1.7835193
339.75	21.341	21.2333	-0.5072221	21.566	21.2333	-1.5668784	21.612	21.2333	-1.7835193

Table C.23 Comparison of τ_{xy} along the mid cross-section of the tube for layer 1, 2, 3 and stacking sequence is $[\pm45/0]_S$ between FEM and CLPT with $\frac{b}{a} = 0.8$

	SXYLAYER 1			**SXYLAYER 2**			**SXYLAYER 3**		
ANGLE (deg)	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**
0	26.443	26.5333	0.34032706	26.483	26.5333	0.1895731	26.557	26.5333	-0.0893217
16.432	25.887	26.5333	2.43580708	25.906	26.5333	2.36419895	26.344	26.5333	0.71344311
34.46	25.723	26.5333	3.05389831	25.776	26.5333	2.85414931	26.284	26.5333	0.93957404
60.03	25.548	26.5333	3.71344688	25.638	26.5333	3.37425047	26.217	26.5333	1.19208692
65.23	25.522	26.5333	3.81143695	25.616	26.5333	3.45716515	26.206	26.5333	1.23354426

Table C.23 – *Continued*

78.8	26.308	26.5333	0.84912167	26.363	26.5333	0.64183498	26.469	26.5333	0.24233699
90	26.304	26.5333	0.86419707	26.36	26.5333	0.65314152	26.466	26.5333	0.25364353
101.2	26.308	26.5333	0.84912167	26.363	26.5333	0.64183498	26.469	26.5333	0.24233699
114.77	25.522	26.5333	3.81143695	25.616	26.5333	3.45716515	26.206	26.5333	1.23354426
119.97	25.548	26.5333	3.71344688	25.638	26.5333	3.37425047	26.217	26.5333	1.19208692
143.54	25.723	26.5333	3.05389831	25.776	26.5333	2.85414931	26.284	26.5333	0.93957404
163.57	25.887	26.5333	2.43580708	25.906	26.5333	2.36419895	26.344	26.5333	0.71344311
180	26.443	26.5333	0.34032706	26.483	26.5333	0.1895731	26.557	26.5333	-0.0893217
196.432	25.887	26.5333	2.43580708	25.906	26.5333	2.36419895	26.344	26.5333	0.71344311
216.46	25.723	26.5333	3.05389831	25.776	26.5333	2.85414931	26.284	26.5333	0.93957404
240.03	25.548	26.5333	3.71344688	25.638	26.5333	3.37425047	26.217	26.5333	1.19208692
245.23	25.522	26.5333	3.81143695	25.616	26.5333	3.45716515	26.206	26.5333	1.23354426
258.8	26.308	26.5333	0.84912167	26.363	26.5333	0.64183498	26.469	26.5333	0.24233699
270	26.304	26.5333	0.86419707	26.36	26.5333	0.65314152	26.466	26.5333	0.25364353
281.2	26.308	26.5333	0.84912167	26.363	26.5333	0.64183498	26.469	26.5333	0.24233699
294.77	25.522	26.5333	3.81143695	25.616	26.5333	3.45716515	26.206	26.5333	1.23354426
299.97	25.548	26.5333	3.71344688	25.638	26.5333	3.37425047	26.217	26.5333	1.19208692
323.54	25.723	26.5333	3.05389831	25.776	26.5333	2.85414931	26.284	26.5333	0.93957404
343.57	25.887	26.5333	2.43580708	25.906	26.5333	2.36419895	26.344	26.5333	0.71344311

Table C.24 Comparison of τ_{xy} along the mid cross-section of the tube for layer 4, 5, 6 and stacking sequence is $[\pm 45/0]_S$ between FEM and CLPT with $\frac{b}{a} = 0.8$

	SXYLAYER 4			SXYLAYER 5			SXYLAYER 6		
ANGLE (deg)	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**
0	26.62	26.5333	-0.3267592	26.672	26.5333	-0.5227394	26.712	26.5333	-0.6734933

Table C.24 – *Continued*

16.432	26.783	26.5333	-0.9410816	27.221	26.5333	-2.5918374	27.459	26.5333	-3.4888235
34.46	26.791	26.5333	-0.9712324	27.298	26.5333	-2.8820388	27.505	26.5333	-3.6621905
60.03	26.796	26.5333	-0.9900766	27.375	26.5333	-3.1722402	27.554	26.5333	-3.8468641
65.23	26.796	26.5333	-0.9900766	27.386	26.5333	-3.2136975	27.576	26.5333	-3.9297788
78.8	26.565	26.5333	-0.1194725	26.653	26.5333	-0.4511312	26.732	26.5333	-0.7488703
90	26.563	26.5333	-0.1119348	26.652	26.5333	-0.4473624	26.732	26.5333	-0.7488703
101.2	26.565	26.5333	-0.1194725	26.653	26.5333	-0.4511312	26.732	26.5333	-0.7488703
114.77	26.796	26.5333	-0.9900766	27.386	26.5333	-3.2136975	27.576	26.5333	-3.9297788
119.97	26.796	26.5333	-0.9900766	27.375	26.5333	-3.1722402	27.554	26.5333	-3.8468641
143.54	26.791	26.5333	-0.9712324	27.298	26.5333	-2.8820388	27.505	26.5333	-3.6621905
163.57	26.783	26.5333	-0.9410816	27.221	26.5333	-2.5918374	27.459	26.5333	-3.4888235
180	26.62	26.5333	-0.3267592	26.672	26.5333	-0.5227394	26.512	26.5333	0.08027648
196.432	26.783	26.5333	-0.9410816	27.221	26.5333	-2.5918374	27.459	26.5333	-3.4888235
216.46	26.791	26.5333	-0.9712324	27.298	26.5333	-2.8820388	27.505	26.5333	-3.6621905
240.03	26.796	26.5333	-0.9900766	27.375	26.5333	-3.1722402	27.554	26.5333	-3.8468641
245.23	26.796	26.5333	-0.9900766	27.386	26.5333	-3.2136975	27.576	26.5333	-3.9297788
258.8	26.565	26.5333	-0.1194725	26.653	26.5333	-0.4511312	26.732	26.5333	-0.7488703
270	26.563	26.5333	-0.1119348	26.652	26.5333	-0.4473624	26.732	26.5333	-0.7488703
281.2	26.565	26.5333	-0.1194725	26.653	26.5333	-0.4511312	26.732	26.5333	-0.7488703
294.77	26.796	26.5333	-0.9900766	27.386	26.5333	-3.2136975	27.576	26.5333	-3.9297788
299.97	26.796	26.5333	-0.9900766	27.375	26.5333	-3.1722402	27.554	26.5333	-3.8468641
323.54	26.791	26.5333	-0.9712324	27.298	26.5333	-2.8820388	27.505	26.5333	-3.6621905
343.57	26.783	26.5333	-0.9410816	27.221	26.5333	-2.5918374	27.459	26.5333	-3.4888235

Table C.25 Comparison of τ_{xy} along the mid cross-section of the tube for layer 1, 2, 3 and stacking sequence is $[\pm45/0]_S$ between FEM and CLPT with $\frac{b}{a} = 0.6$

	SXYLAYER 1			SXYLAYER 2			SXYLAYER 3		
ANGLE (deg)	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**
0	35.179	35.3667	0.53072523	35.279	35.3667	0.24797338	35.36	35.3667	0.01894437
12.46	34.562	35.3667	2.27530417	34.649	35.3667	2.02931006	35.136	35.3667	0.65230853
28.98	34.348	35.3667	2.88039314	34.337	35.3667	2.91149584	35.027	35.3667	0.96050805
44.16	34.135	35.3667	3.48265459	34.125	35.3667	3.51092977	34.915	35.3667	1.27719013
58.38	34.06	35.3667	3.69471848	34.025	35.3667	3.79368163	34.898	35.3667	1.32525794
75.21	34.971	35.3667	1.11884909	35.147	35.3667	0.62120582	35.312	35.3667	0.15466526
90	34.963	35.3667	1.14146924	35.142	35.3667	0.63534342	35.309	35.3667	0.16314782
104.79	34.971	35.3667	1.11884909	35.147	35.3667	0.62120582	35.312	35.3667	0.15466526
121.62	34.06	35.3667	3.69471848	34.025	35.3667	3.79368163	34.898	35.3667	1.32525794
135.84	34.135	35.3667	3.48265459	34.025	35.3667	3.79368163	34.915	35.3667	1.27719013
151.02	34.348	35.3667	2.88039314	34.337	35.3667	2.91149584	35.027	35.3667	0.96050805
167.54	34.562	35.3667	2.27530417	34.649	35.3667	2.02931006	35.136	35.3667	0.65230853
180	35.179	35.3667	0.53072523	35.279	35.3667	0.24797338	35.36	35.3667	0.01894437
192.46	34.562	35.3667	2.27530417	34.649	35.3667	2.02931006	35.136	35.3667	0.65230853
208.98	34.348	35.3667	2.88039314	34.337	35.3667	2.91149584	35.027	35.3667	0.96050805
224.16	34.135	35.3667	3.48265459	34.125	35.3667	3.51092977	34.915	35.3667	1.27719013
238.38	34.06	35.3667	3.69471848	34.025	35.3667	3.79368163	34.898	35.3667	1.32525794
255.21	34.971	35.3667	1.11884909	35.147	35.3667	0.62120582	35.312	35.3667	0.15466526
270	34.963	35.3667	1.14146924	35.142	35.3667	0.63534342	35.309	35.3667	0.16314782
284.79	34.971	35.3667	1.11884909	35.147	35.3667	0.62120582	35.312	35.3667	0.15466526
301.62	34.06	35.3667	3.69471848	34.025	35.3667	3.79368163	34.898	35.3667	1.32525794

Table C.25 – *Continued*

315.84	34.135	35.3667	3.48265459	34.125	35.3667	3.51092977	34.915	35.3667	1.27719013
331.02	34.348	35.3667	2.88039314	34.337	35.3667	2.91149584	35.027	35.3667	0.96050805
347.54	34.562	35.3667	2.27530417	34.649	35.3667	2.02931006	35.136	35.3667	0.65230853

Table C.26 Comparison of τ_{xy} along the mid cross-section of the tube for layer 4, 5, 6 and stacking sequence is $[\pm 45/0]_S$ between FEM and CLPT with $\frac{b}{a} = 0.6$

	SXYLAYER 4			**SXYLAYER 5**			**SXYLAYER 6**		
ANGLE (deg)	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**
0	35.421	35.3667	-0.1535343	35.462	35.3667	-0.2694625	35.483	35.3667	-0.3288404
12.46	35.623	35.3667	-0.724693	36.109	35.3667	-2.098867	36.596	35.3667	-3.4758685
28.98	35.716	35.3667	-0.9876522	36.405	35.3667	-2.9358125	36.694	35.3667	-3.7529654
44.16	35.805	35.3667	-1.2393014	36.694	35.3667	-3.7529654	36.884	35.3667	-4.2901939
58.38	35.817	35.3667	-1.2732316	36.737	35.3667	-3.8745487	36.656	35.3667	-3.6455197
75.21	35.467	35.3667	-0.2836001	35.611	35.3667	-0.6907628	35.744	35.3667	-1.0668227
90	35.467	35.3667	-0.2836001	35.614	35.3667	-0.6992453	35.75	35.3667	-1.0837879
104.79	35.467	35.3667	-0.2836001	35.611	35.3667	-0.6907628	35.744	35.3667	-1.0668227
121.62	35.817	35.3667	-1.2732316	36.737	35.3667	-3.8745487	36.656	35.3667	-3.6455197
135.84	35.805	35.3667	-1.2393014	36.694	35.3667	-3.7529654	36.884	35.3667	-4.2901939
151.02	35.716	35.3667	-0.9876522	36.405	35.3667	-2.9358125	36.694	35.3667	-3.7529654
167.54	35.623	35.3667	-0.724693	36.109	35.3667	-2.098867	36.596	35.3667	-3.4758685
180	35.421	35.3667	-0.1535343	35.462	35.3667	-0.2694625	35.483	35.3667	-0.3288404
192.46	35.623	35.3667	-0.724693	36.109	35.3667	-2.098867	36.596	35.3667	-3.4758685
208.98	35.716	35.3667	-0.9876522	36.405	35.3667	-2.9358125	36.694	35.3667	-3.7529654
224.16	35.805	35.3667	-1.2393014	36.694	35.3667	-3.7529654	36.884	35.3667	-4.2901939
238.38	35.817	35.3667	-1.2732316	36.737	35.3667	-3.8745487	36.656	35.3667	-3.6455197

Table C.26 – *Continued*

255.21	35.467	35.3667	-0.2836001	35.611	35.3667	-0.6907628	35.744	35.3667	-1.0668227
270	35.467	35.3667	-0.2836001	35.614	35.3667	-0.6992453	35.75	35.3667	-1.0837879
284.79	35.467	35.3667	-0.2836001	35.611	35.3667	-0.6907628	35.744	35.3667	-1.0668227
301.62	35.817	35.3667	-1.2732316	36.737	35.3667	-3.8745487	36.656	35.3667	-3.6455197
315.84	35.805	35.3667	-1.2393014	36.694	35.3667	-3.7529654	36.884	35.3667	-4.2901939
331.02	35.716	35.3667	-0.9876522	36.405	35.3667	-2.9358125	36.694	35.3667	-3.7529654
347.54	35.623	35.3667	-0.724693	36.109	35.3667	-2.098867	36.596	35.3667	-3.4758685

Table C.27 Comparison of τ_{xy} along the mid cross-section of the tube for layer 1, 2, 3 and stacking sequence is $[\pm 45/0]_S$ between FEM and CLPT with $\frac{b}{a} = 0.4$

	SXYLAYER 1			**SXYLAYER 2**			**SXYLAYER 3**		
ANGLE (deg)	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**
0	52.529	53.0667	1.01325313	52.682	53.0667	0.72493673	52.789	53.0667	0.52330369
8.35	51.267	53.0667	3.39139234	51.921	53.0667	2.15898106	52.574	53.0667	0.92845419
20.25	50.957	53.0667	3.97556283	51.17	53.0667	3.57418117	52.383	53.0667	1.28837859
40.9	50.234	53.0667	5.33799916	50.562	53.0667	4.7199091	52.265	53.0667	1.51074026
47.27	50.034	53.0667	5.71488334	50.483	53.0667	4.86877835	52.253	53.0667	1.53335331
68.4	52.429	53.0667	1.20169523	52.76	53.0667	0.5779519	53.078	53.0667	-0.021294
90	52.423	53.0667	1.21300175	52.76	53.0667	0.5779519	53.084	53.0667	-0.0326005
111.6	52.429	53.0667	1.20169523	52.76	53.0667	0.5779519	53.078	53.0667	-0.021294
132.73	50.034	53.0667	5.71488334	50.483	53.0667	4.86877835	52.253	53.0667	1.53335331
139.1	50.234	53.0667	5.33799916	50.562	53.0667	4.7199091	52.265	53.0667	1.51074026
159.75	50.957	53.0667	3.97556283	51.17	53.0667	3.57418117	52.383	53.0667	1.28837859
171.65	51.267	53.0667	3.39139234	51.921	53.0667	2.15898106	52.574	53.0667	0.92845419
180	52.529	53.0667	1.01325313	52.682	53.0667	0.72493673	52.789	53.0667	0.52330369

Table C.27 – *Continued*

188.35	51.267	53.0667	3.39139234	51.921	53.0667	2.15898106	52.574	53.0667	0.92845419
200.25	50.957	53.0667	3.97556283	51.17	53.0667	3.57418117	52.383	53.0667	1.28837859
220.9	50.234	53.0667	5.33799916	50.562	53.0667	4.7199091	52.265	53.0667	1.51074026
227.27	50.034	53.0667	5.71488334	50.483	53.0667	4.86877835	52.253	53.0667	1.53335331
248.4	52.429	53.0667	1.20169523	52.76	53.0667	0.5779519	53.078	53.0667	-0.021294
270	52.423	53.0667	1.21300175	52.76	53.0667	0.5779519	53.084	53.0667	-0.0326005
291.6	52.429	53.0667	1.20169523	52.76	53.0667	0.5779519	53.078	53.0667	-0.021294
312.73	50.034	53.0667	5.71488334	50.483	53.0667	4.86877835	52.253	53.0667	1.53335331
319.1	50.234	53.0667	5.33799916	50.562	53.0667	4.7199091	52.265	53.0667	1.51074026
339.75	49.957	53.0667	5.85998376	51.17	53.0667	3.57418117	52.383	53.0667	1.28837859
351.65	51.267	53.0667	3.39139234	51.921	53.0667	2.15898106	52.574	53.0667	0.92845419

Table C.28 Comparison of τ_{xy} along the mid cross-section of the tube for layer 4, 5, 6 and stacking sequence is $[\pm 45/0]_S$ between FEM and CLPT with $\frac{b}{a} = 0.4$

	SXYLAYER 4			SXYLAYER 5			SXYLAYER 6		
ANGLE (deg)	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**
0	52.85	53.0667	0.40835401	52.866	53.0667	0.37820328	52.836	53.0667	0.43473591
8.35	53.228	53.0667	-0.3039571	53.882	53.0667	-1.5363684	54.535	53.0667	-2.7668952
20.25	53.596	53.0667	-0.997424	54.809	53.0667	-3.2832266	56.022	53.0667	-5.5690292
40.9	53.968	53.0667	-1.6984286	55.671	53.0667	-4.9075974	56.374	53.0667	-6.2323453
47.27	54.024	53.0667	-1.8039562	55.794	53.0667	-5.1393812	56.565	53.0667	-6.5922697
68.4	53.382	53.0667	-0.5941579	53.672	53.0667	-1.14064	53.948	53.0667	-1.6607402
90	53.395	53.0667	-0.6186554	53.692	53.0667	-1.1783284	53.975	53.0667	-1.7116195
111.6	53.382	53.0667	-0.5941579	53.672	53.0667	-1.14064	53.948	53.0667	-1.6607402
132.73	54.024	53.0667	-1.8039562	55.794	53.0667	-5.1393812	56.565	53.0667	-6.5922697

Table C.28 – *Continued*

139.1	53.968	53.0667	-1.6984286	55.671	53.0667	-4.9075974	56.374	53.0667	-6.2323453
159.75	53.596	53.0667	-0.997424	54.809	53.0667	-3.2832266	56.022	53.0667	-5.5690292
171.65	53.228	53.0667	-0.3039571	53.882	53.0667	-1.5363684	54.535	53.0667	-2.7668952
180	52.85	53.0667	0.40835401	52.866	53.0667	0.37820328	52.836	53.0667	0.43473591
188.35	53.228	53.0667	-0.3039571	53.882	53.0667	-1.5363684	54.535	53.0667	-2.7668952
200.25	53.596	53.0667	-0.997424	54.809	53.0667	-3.2832266	56.022	53.0667	-5.5690292
220.9	53.968	53.0667	-1.6984286	55.671	53.0667	-4.9075974	56.374	53.0667	-6.2323453
227.27	54.024	53.0667	-1.8039562	55.794	53.0667	-5.1393812	56.565	53.0667	-6.5922697
248.4	53.382	53.0667	-0.5941579	53.672	53.0667	-1.14064	53.948	53.0667	-1.6607402
270	53.395	53.0667	-0.6186554	53.692	53.0667	-1.1783284	53.975	53.0667	-1.7116195
291.6	53.382	53.0667	-0.5941579	53.672	53.0667	-1.14064	53.948	53.0667	-1.6607402
312.73	54.024	53.0667	-1.8039562	55.794	53.0667	-5.1393812	56.565	53.0667	-6.5922697
319.1	53.968	53.0667	-1.6984286	55.671	53.0667	-4.9075974	56.374	53.0667	-6.2323453
339.75	53.596	53.0667	-0.997424	54.809	53.0667	-3.2832266	56.022	53.0667	-5.5690292
351.65	53.228	53.0667	-0.3039571	53.882	53.0667	-1.5363684	54.535	53.0667	-2.7668952

Table C.29 Comparison of τ_{xy} along the mid cross-section of the tube for layer 1, 2, 3 and stacking sequence is $[\pm 45/0]_S$ between FEM and CLPT with $\frac{b}{a} = 0.2$

	SXYLAYER 1			**SXYLAYER 2**			**SXYLAYER 3**		
ANGLE (deg)	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**
0	103.47	106.103	2.48182667	103.9	106.103	2.07656124	104.14	106.103	1.85036658
4.18	101.64	106.103	4.20656096	103.15	106.103	2.78341955	104.66	106.103	1.36027814
10.44	99.661	106.103	6.07172444	101.631	106.103	4.21504326	103.6	106.103	2.35930456
23.41	96.066	106.103	9.45993197	100.989	106.103	4.82011398	102.91	106.103	3.00961422
28.42	97.483	106.103	8.12444099	100.659	106.103	5.13113164	102.84	106.103	3.07558766

Table C.29 – *Continued*

51.62	103.2	106.103	2.73629567	104.38	106.103	1.62417192	105.54	106.103	0.53089772
90	103.14	106.103	2.79284433	104.36	106.103	1.64302147	105.55	106.103	0.52147294
128.38	103.2	106.103	2.73629567	104.38	106.103	1.62417192	105.54	106.103	0.53089772
151.58	97.483	106.103	8.12444099	100.659	106.103	5.13113164	102.84	106.103	3.07558766
156.59	96.066	106.103	9.45993197	100.989	106.103	4.82011398	102.91	106.103	3.00961422
169.56	99.661	106.103	6.07172444	101.631	106.103	4.21504326	103.6	106.103	2.35930456
177.59	101.64	106.103	4.20656096	103.15	106.103	2.78341955	104.66	106.103	1.36027814
180	103.47	106.103	2.48182667	103.9	106.103	2.07656124	104.14	106.103	1.85036658
184.18	101.64	106.103	4.20656096	103.15	106.103	2.78341955	104.66	106.103	1.36027814
190.44	99.661	106.103	6.07172444	101.631	106.103	4.21504326	103.6	106.103	2.35930456
203.41	96.066	106.103	9.45993197	100.989	106.103	4.82011398	102.91	106.103	3.00961422
208.42	97.483	106.103	8.12444099	100.659	106.103	5.13113164	102.84	106.103	3.07558766
231.62	103.2	106.103	2.73629567	104.38	106.103	1.62417192	105.54	106.103	0.53089772
270	103.14	106.103	2.79284433	104.36	106.103	1.64302147	105.55	106.103	0.52147294
308.38	103.14	106.103	2.79284433	104.38	106.103	1.62417192	105.54	106.103	0.53089772
331.58	97.483	106.103	8.12444099	100.659	106.103	5.13113164	102.84	106.103	3.07558766
336.59	96.066	106.103	9.45993197	100.989	106.103	4.82011398	102.91	106.103	3.00961422
349.56	99.661	106.103	6.07172444	101.631	106.103	4.21504326	103.6	106.103	2.35930456
355.82	101.64	106.103	4.20656096	103.15	106.103	2.78341955	104.66	106.103	1.36027814

Table C.30 Comparison of τ_{xy} along the mid cross-section of the tube for layer 4, 5, 6 and stacking sequence is $[\pm 45/0]_S$ between FEM and CLPT with $\frac{b}{a} = 0.2$

	SXYLAYER 4			**SXYLAYER 5**			**SXYLAYER 6**		
ANGLE (deg)	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**
0	104.2	106.103	1.79381791	104.08	106.103	1.90691524	103.78	106.103	2.18965857

Table C.30 – *Continued*

4.18	106.16	106.103	-0.0534385	107.67	106.103	-1.4765799	109.18	106.103	-2.8997213
10.44	107.57	106.103	-1.3823321	109.54	106.103	-3.2390133	112.51	106.103	-6.0381722
23.41	108.83	106.103	-2.5698541	110.76	106.103	-4.3888362	114.68	106.103	-8.083349
28.42	109.01	106.103	-2.7395001	111.19	106.103	-4.7941016	115.36	106.103	-8.7242338
51.62	106.68	106.103	-0.5435269	107.8	106.103	-1.599102	108.89	106.103	-2.6264028
90	106.72	106.103	-0.581226	107.87	106.103	-1.6650755	108.99	106.103	-2.7206505
128.38	106.68	106.103	-0.5435269	107.8	106.103	-1.599102	108.89	106.103	-2.6264028
151.58	109.01	106.103	-2.7395001	111.19	106.103	-4.7941016	115.36	106.103	-8.7242338
156.59	108.83	106.103	-2.5698541	110.76	106.103	-4.3888362	114.68	106.103	-8.083349
169.56	107.57	106.103	-1.3823321	109.54	106.103	-3.2390133	112.51	106.103	-6.0381722
177.59	106.16	106.103	-0.0534385	107.67	106.103	-1.4765799	109.18	106.103	-2.8997213
180	104.2	106.103	1.79381791	104.08	106.103	1.90691524	103.78	106.103	2.18965857
184.18	106.16	106.103	-0.0534385	107.67	106.103	-1.4765799	109.18	106.103	-2.8997213
190.44	107.57	106.103	-1.3823321	109.54	106.103	-3.2390133	112.51	106.103	-6.0381722
203.41	108.83	106.103	-2.5698541	110.76	106.103	-4.3888362	114.68	106.103	-8.083349
208.42	109.01	106.103	-2.7395001	111.19	106.103	-4.7941016	115.36	106.103	-8.7242338
231.62	106.68	106.103	-0.5435269	107.8	106.103	-1.599102	108.89	106.103	-2.6264028
270	106.72	106.103	-0.581226	107.87	106.103	-1.6650755	108.99	106.103	-2.7206505
308.38	106.68	106.103	-0.5435269	107.8	106.103	-1.599102	108.89	106.103	-2.6264028
331.58	109.01	106.103	-2.7395001	111.19	106.103	-4.7941016	115.36	106.103	-8.7242338
336.59	108.83	106.103	-2.5698541	110.76	106.103	-4.3888362	114.68	106.103	-8.083349
349.56	107.57	106.103	-1.3823321	109.54	106.103	-3.2390133	112.51	106.103	-6.0381722
355.82	106.16	106.103	-0.0534385	107.67	106.103	-1.4765799	109.18	106.103	-2.8997213

Table C.31 Comparison of τ_{xy} along the mid cross-section of the tube for layer 1, 2, 3 and stacking sequence is [+45/-45/0/0/45/-45] between FEM and CLPT with $\frac{b}{a} = 1$

	SXYLAYER 1			SXYLAYER 2			SXYLAYER 3		
ANGLE (deg)	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**
0	21.878	16.1715	-35.287388	23.463	28.7945	18.51568876	5.1479	5.4681	5.855781716
20.25	22.819	16.1715	-41.106267	25.05	28.7945	13.00421956	5.2317	5.4681	4.323256707
42.75	22.819	16.1715	-41.106267	25.05	28.7945	13.00421956	5.2317	5.4681	4.323256707
65.25	22.819	16.1715	-41.106267	25.05	28.7945	13.00421956	5.2317	5.4681	4.323256707
69.75	22.819	16.1715	-41.106267	25.05	28.7945	13.00421956	5.2317	5.4681	4.323256707
81	21.878	16.1715	-35.287388	23.463	28.7945	18.51568876	5.1479	5.4681	5.855781716
90	21.878	16.1715	-35.287388	23.463	28.7945	18.51568876	5.1479	5.4681	5.855781716
99	21.878	16.1715	-35.287388	23.463	28.7945	18.51568876	5.1479	5.4681	5.855781716
110.25	22.819	16.1715	-41.106267	25.05	28.7945	13.00421956	5.2317	5.4681	4.323256707
137.25	22.819	16.1715	-41.106267	25.05	28.7945	13.00421956	5.2317	5.4681	4.323256707
155.75	22.819	16.1715	-41.106267	25.05	28.7945	13.00421956	5.2317	5.4681	4.323256707
159.75	22.819	16.1715	-41.106267	25.05	28.7945	13.00421956	5.2317	5.4681	4.323256707
180	21.878	16.1715	-35.287388	23.463	28.7945	18.51568876	5.1479	5.4681	5.855781716
200.25	22.819	16.1715	-41.106267	25.05	28.7945	13.00421956	5.2317	5.4681	4.323256707
222.75	22.819	16.1715	-41.106267	25.05	28.7945	13.00421956	5.2317	5.4681	4.323256707
245.25	22.819	16.1715	-41.106267	25.05	28.7945	13.00421956	5.2317	5.4681	4.323256707
249.75	22.819	16.1715	-41.106267	25.05	28.7945	13.00421956	5.2317	5.4681	4.323256707
261	21.878	16.1715	-35.287388	23.463	28.7945	18.51568876	5.1479	5.4681	5.855781716
270	21.878	16.1715	-35.287388	23.463	28.7945	18.51568876	5.1479	5.4681	5.855781716
279	21.878	16.1715	-35.287388	23.463	28.7945	18.51568876	5.1479	5.4681	5.855781716
290.25	22.819	16.1715	-41.106267	25.05	28.7945	13.00421956	5.2317	5.4681	4.323256707

Table C.31 – *Continued*

294.75	22.819	16.1715	-41.1062672	25.05	28.7945	13.00421956	5.2317	5.4681	4.323256707
317.25	22.819	16.1715	-41.1062672	25.05	28.7945	13.00421956	5.2317	5.4681	4.323256707
339.75	22.819	16.1715	-41.1062672	25.05	28.7945	13.00421956	5.2317	5.4681	4.323256707

Table C.32 Comparison of τ_{xy} along the mid cross-section of the tube for layer 4, 5, 6 and stacking sequence is [+45/-45/0/0/45/-45] between FEM and CLPT with $\frac{b}{a} = 1$

	SXYLAYER 4			**SXYLAYER 5**			**SXYLAYER 6**		
ANGLE (deg)	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**
0	35.596	38.2377	6.908626826	33.81	31.0586	-8.85873799	7.3645	7.6695	3.976791186
20.25	34.699	38.2377	9.254479218	32.819	31.0586	-5.66799533	7.1105	7.6695	7.288610731
42.75	34.699	38.2377	9.254479218	32.819	31.0586	-5.66799533	7.1105	7.6695	7.288610731
65.25	34.699	38.2377	9.254479218	32.819	31.0586	-5.66799533	7.1105	7.6695	7.288610731
69.75	34.699	38.2377	9.254479218	32.819	31.0586	-5.66799533	7.1105	7.6695	7.288610731
81	35.596	38.2377	6.908626826	33.81	31.0586	-8.85873799	7.3645	7.6695	3.976791186
90	35.596	38.2377	6.908626826	33.81	31.0586	-8.85873799	7.3645	7.6695	3.976791186
99	35.596	38.2377	6.908626826	33.81	31.0586	-8.85873799	7.3645	7.6695	3.976791186
110.25	34.699	38.2377	9.254479218	32.819	31.0586	-5.66799533	7.1105	7.6695	7.288610731
137.25	34.699	38.2377	9.254479218	32.819	31.0586	-5.66799533	7.1105	7.6695	7.288610731
155.75	34.699	38.2377	9.254479218	32.819	31.0586	-5.66799533	7.1105	7.6695	7.288610731
159.75	34.699	38.2377	9.254479218	32.819	31.0586	-5.66799533	7.1105	7.6695	7.288610731
180	35.596	38.2377	6.908626826	33.81	31.0586	-8.85873799	7.3645	7.6695	3.976791186
200.25	34.699	38.2377	9.254479218	32.819	31.0586	-5.66799533	7.1105	7.6695	7.288610731
222.75	34.699	38.2377	9.254479218	32.819	31.0586	-5.66799533	7.1105	7.6695	7.288610731
245.25	34.699	38.2377	9.254479218	32.819	31.0586	-5.66799533	7.1105	7.6695	7.288610731
249.75	34.699	38.2377	9.254479218	32.819	31.0586	-5.66799533	7.1105	7.6695	7.288610731

Table C.32 – *Continued*

261	35.596	38.2377	6.908626826	33.81	31.0586	-8.85873799	7.3645	7.6695	3.976791186
270	35.596	38.2377	6.908626826	33.81	31.0586	-8.85873799	7.3645	7.6695	3.976791186
279	35.596	38.2377	6.908626826	33.81	31.0586	-8.85873799	7.3645	7.6695	3.976791186
290.25	34.699	38.2377	9.254479218	32.819	31.0586	-5.66799533	7.1105	7.6695	7.288610731
294.75	34.699	38.2377	9.254479218	32.819	31.0586	-5.66799533	7.1105	7.6695	7.288610731
317.25	34.699	38.2377	9.254479218	32.819	31.0586	-5.66799533	7.1105	7.6695	7.288610731
339.75	34.699	38.2377	9.254479218	32.819	31.0586	-5.66799533	7.1105	7.6695	7.288610731

Table C.33 Comparison of τ_{xy} along the mid cross-section of the tube for layer 1, 2, 3 and stacking sequence is [+45/-45/0/0/45/-45] between FEM and CLPT with $\frac{b}{a} = 0.8$

	SXYLAYER 1			**SXYLAYER 2**			**SXYLAYER 3**		
ANGLE (deg)	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**
0	27.167	20.2081	-34.4361914	29.197	35.9818	18.85619952	6.4239	6.8329	5.985745438
16.432	28.588	20.2081	-41.4680252	31.148	35.9818	13.43401386	6.526	6.8329	4.491504339
34.46	28.588	20.2081	-41.4680252	31.148	35.9818	13.43401386	6.532	6.8329	4.403693893
60.03	28.588	20.2081	-41.4680252	31.148	35.9818	13.43401386	6.5381	6.8329	4.314419939
65.23	28.588	20.2081	-41.4680252	31.148	35.9818	13.43401386	6.539	6.8329	4.301248372
78.8	27.368	20.2081	-35.4308420	29.317	35.9818	18.52269759	6.4546	6.8329	5.536448653
90	27.373	20.2081	-35.4555846	29.32	35.9818	18.51436004	6.4552	6.8329	5.527667608
101.2	27.368	20.2081	-35.4308420	29.317	35.9818	18.52269759	6.4546	6.8329	5.536448653
114.77	28.588	20.2081	-41.4680252	31.148	35.9818	13.43401386	6.539	6.8329	4.301248372
119.97	28.588	20.2081	-41.4680252	31.148	35.9818	13.43401386	6.5381	6.8329	4.314419939
143.54	28.588	20.2081	-41.4680252	31.148	35.9818	13.43401386	6.532	6.8329	4.403693893
163.57	28.588	20.2081	-41.4680252	31.148	35.9818	13.43401386	6.526	6.8329	4.491504339
180	27.167	20.2081	-34.4361914	29.197	35.9818	18.85619952	6.4239	6.8329	5.985745438

Table C.33 – *Continued*

196.432	28.588	20.2081	-41.4680252	31.148	35.9818	13.43401386	6.526	6.8329	4.491504339
216.46	28.588	20.2081	-41.4680252	31.148	35.9818	13.43401386	6.532	6.8329	4.403693893
240.03	28.588	20.2081	-41.4680252	31.148	35.9818	13.43401386	6.5381	6.8329	4.314419939
245.23	28.588	20.2081	-41.4680252	31.148	35.9818	13.43401386	6.539	6.8329	4.301248372
258.8	27.368	20.2081	-35.4308420	29.317	35.9818	18.52269759	6.5398	6.8329	4.289540312
270	27.373	20.2081	-35.4555846	29.32	35.9818	18.51436004	6.4552	6.8329	5.527667608
281.2	27.368	20.2081	-35.4308420	29.317	35.9818	18.52269759	6.4546	6.8329	5.536448653
294.77	28.588	20.2081	-41.4680252	31.148	35.9818	13.43401386	6.539	6.8329	4.301248372
299.97	28.588	20.2081	-41.4680252	31.148	35.9818	13.43401386	6.5381	6.8329	4.314419939
323.54	28.588	20.2081	-41.4680252	31.148	35.9818	13.43401386	6.532	6.8329	4.403693893
343.57	28.588	20.2081	-41.4680252	31.148	35.9818	13.43401386	6.526	6.8329	4.491504339

Table C.34 Comparison of τ_{xy} along the mid cross-section of the tube for layer 4, 5, 6 and stacking sequence is [+45/-45/0/0/45/-45] between FEM and CLPT with $\frac{b}{a} = 0.8$

	SXYLAYER 4			**SXYLAYER 5**			**SXYLAYER 6**		
ANGLE (deg)	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**
0	44.577	47.7821	6.707742021	42.308	38.6184	-9.55399498	9.2385	9.5839	3.603960809
16.432	43.863	47.7821	8.202025445	41.45	38.6184	-7.33225612	8.735	9.5839	8.857563205
34.46	43.863	47.7821	8.202025445	41.45	38.6184	-7.33225612	8.735	9.5839	8.857563205
60.03	43.863	47.7821	8.202025445	41.45	38.6184	-7.33225612	8.735	9.5839	8.857563205
65.23	43.863	47.7821	8.202025445	41.45	38.6184	-7.33225612	8.735	9.5839	8.857563205
78.8	44.52	47.7821	6.827033554	42.375	38.6184	-9.72748741	9.226	9.5839	3.73438788
90	44.517	47.7821	6.833312056	42.376	38.6184	-9.73007685	9.2256	9.5839	3.738561546
101.2	44.52	47.7821	6.827033554	42.375	38.6184	-9.72748741	9.226	9.5839	3.73438788
114.77	43.863	47.7821	8.202025445	41.45	38.6184	-7.33225612	8.735	9.5839	8.857563205

Table C.34 – *Continued*

119.97	43.863	47.7821	8.202025445	41.45	38.6184	-7.33225612	8.735	9.5839	8.857563205
143.54	43.863	47.7821	8.202025445	41.45	38.6184	-7.33225612	8.735	9.5839	8.857563205
163.57	43.863	47.7821	8.202025445	41.45	38.6184	-7.33225612	8.735	9.5839	8.857563205
180	44.577	47.7821	6.707742021	42.308	38.6184	-9.55399498	9.2385	9.5839	3.603960809
196.432	43.863	47.7821	8.202025445	41.45	38.6184	-7.33225612	8.735	9.5839	8.857563205
216.46	43.863	47.7821	8.202025445	41.45	38.6184	-7.33225612	8.735	9.5839	8.857563205
240.03	43.863	47.7821	8.202025445	41.45	38.6184	-7.33225612	8.735	9.5839	8.857563205
245.23	43.863	47.7821	8.202025445	41.45	38.6184	-7.33225612	8.735	9.5839	8.857563205
258.8	44.52	47.7821	6.827033554	42.375	38.6184	-9.72748741	9.226	9.5839	3.73438788
270	44.517	47.7821	6.833312056	42.376	38.6184	-9.73007685	9.2256	9.5839	3.738561546
281.2	44.52	47.7821	6.827033554	42.375	38.6184	-9.72748741	9.226	9.5839	3.73438788
294.77	43.863	47.7821	8.202025445	41.45	38.6184	-7.33225612	8.735	9.5839	8.857563205
299.97	43.863	47.7821	8.202025445	41.45	38.6184	-7.33225612	8.735	9.5839	8.857563205
323.54	43.863	47.7821	8.202025445	41.45	38.6184	-7.33225612	8.735	9.5839	8.857563205
343.57	43.863	47.7821	8.202025445	41.45	38.6184	-7.33225612	8.735	9.5839	8.857563205

Table C.35 Comparison of τ_{xy} along the mid cross-section of the tube for layer 1, 2, 3 and stacking sequence is [+45/-45/0/0/45/-45] between FEM and CLPT with $\frac{b}{a} = 0.6$

	SXYLAYER 1			SXYLAYER 2			SXYLAYER 3		
ANGLE (deg)	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)2**	**Analytical Result (lb-in)2**	**Miss Match (%)2**	**FEM Result (lb-in)3**	**Analytical Result (lb-in)3**	**Miss Match (%)3**
0	35.941	26.9356	-33.4330774	38.642	47.9607	19.42986654	8.5305	9.1077	6.337494647
12.46	37.831	26.9356	-40.4498136	41.415	47.9607	13.64804934	8.6702	9.1077	4.8036277
28.98	37.831	26.9356	-40.4498136	41.415	47.9607	13.64804934	8.6977	9.1077	4.501685387
44.16	37.831	26.9356	-40.4498136	41.415	47.9607	13.64804934	8.7285	9.1077	4.163509997
58.38	37.831	26.9356	-40.4498136	41.415	47.9607	13.64804934	8.7333	9.1077	4.110807339

Table C.35 – *Continued*

75.21	36.566	26.9356	-35.7534266	39.194	47.9607	18.2789242	8.6488	9.1077	5.038593717
90	36.581	26.9356	-35.8091150	39.207	47.9607	18.25181868	8.6512	9.1077	5.012242388
104.79	36.566	26.9356	-35.7534266	39.194	47.9607	18.2789242	8.6488	9.1077	5.038593717
121.62	37.831	26.9356	-40.4498136	41.415	47.9607	13.64804934	8.7333	9.1077	4.110807339
135.84	37.831	26.9356	-40.4498136	41.415	47.9607	13.64804934	8.7285	9.1077	4.163509997
151.02	37.831	26.9356	-40.4498136	41.415	47.9607	13.64804934	8.6977	9.1077	4.501685387
167.54	37.831	26.9356	-40.4498136	41.415	47.9607	13.64804934	8.6702	9.1077	4.8036277
180	35.941	26.9356	-33.4330774	38.642	47.9607	19.42986654	8.5305	9.1077	6.337494647
192.46	37.831	26.9356	-40.4498136	41.415	47.9607	13.64804934	8.6702	9.1077	4.8036277
208.98	37.831	26.9356	-40.4498136	41.415	47.9607	13.64804934	8.6977	9.1077	4.501685387
224.16	37.831	26.9356	-40.4498136	41.415	47.9607	13.64804934	8.7285	9.1077	4.163509997
238.38	37.831	26.9356	-40.4498136	41.415	47.9607	13.64804934	8.7333	9.1077	4.110807339
255.21	36.566	26.9356	-35.7534266	39.194	47.9607	18.2789242	8.6488	9.1077	5.038593717
270	36.581	26.9356	-35.8091150	39.207	47.9607	18.25181868	8.6512	9.1077	5.012242388
284.79	36.566	26.9356	-35.7534266	39.194	47.9607	18.2789242	8.6488	9.1077	5.038593717
301.62	37.831	26.9356	-40.4498136	41.415	47.9607	13.64804934	8.7333	9.1077	4.110807339
315.84	37.831	26.9356	-40.4498136	41.415	47.9607	13.64804934	8.7285	9.1077	4.163509997
331.02	37.831	26.9356	-40.4498136	41.415	47.9607	13.64804934	8.6977	9.1077	4.501685387
347.54	37.831	26.9356	-40.4498136	41.415	47.9607	13.64804934	8.6702	9.1077	4.8036277

Table C.36 Comparison of τ_{xy} along the mid cross-section of the tube for layer 4, 5, 6 and stacking sequence is [+45/-45/0/0/45/-45] between FEM and CLPT with $\frac{b}{a} = 0.6$

	SXYLAYER 4			**SXYLAYER 5**			**SXYLAYER 6**		
ANGLE (deg)	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**
0	59.4	63.6895	6.735019116	56.327	51.7319	-8.88252702	12.327	12.7746	3.503827909

Table C.36 – *Continued*

12.46	57.998	63.6895	8.936323884	55.212	51.7319	-6.72718380	11.907	12.7746	6.791602085
28.98	57.998	63.6895	8.936323884	55.212	51.7319	-6.72718380	11.907	12.7746	6.791602085
44.16	57.998	63.6895	8.936323884	55.212	51.7319	-6.72718380	11.907	12.7746	6.791602085
58.38	57.998	63.6895	8.936323884	55.212	51.7319	-6.72718380	11.907	12.7746	6.791602085
75.21	59.521	63.6895	6.545034896	56.75	51.7319	-9.70020432	12.351	12.7746	3.315955098
90	59.523	63.6895	6.541894661	56.76	51.7319	-9.71953475	12.351	12.7746	3.315955098
104.79	59.521	63.6895	6.545034896	56.75	51.7319	-9.70020432	12.351	12.7746	3.315955098
121.62	57.998	63.6895	8.936323884	55.212	51.7319	-6.72718380	11.907	12.7746	6.791602085
135.84	57.998	63.6895	8.936323884	55.212	51.7319	-6.72718380	11.907	12.7746	6.791602085
151.02	57.998	63.6895	8.936323884	55.212	51.7319	-6.72718380	11.907	12.7746	6.791602085
167.54	57.998	63.6895	8.936323884	55.212	51.7319	-6.72718380	11.907	12.7746	6.791602085
180	59.4	63.6895	6.735019116	56.327	51.7319	-8.88252702	12.327	12.7746	3.503827909
192.46	57.998	63.6895	8.936323884	55.212	51.7319	-6.72718380	11.907	12.7746	6.791602085
208.98	57.998	63.6895	8.936323884	55.212	51.7319	-6.72718380	11.907	12.7746	6.791602085
224.16	57.998	63.6895	8.936323884	55.212	51.7319	-6.72718380	11.907	12.7746	6.791602085
238.38	57.998	63.6895	8.936323884	55.212	51.7319	-6.72718380	11.907	12.7746	6.791602085
255.21	59.521	63.6895	6.545034896	56.75	51.7319	-9.70020432	12.351	12.7746	3.315955098
270	59.523	63.6895	6.541894661	56.76	51.7319	-9.71953475	12.351	12.7746	3.315955098
284.79	59.521	63.6895	6.545034896	56.75	51.7319	-9.70020432	12.351	12.7746	3.315955098
301.62	57.998	63.6895	8.936323884	55.212	51.7319	-6.72718380	11.907	12.7746	6.791602085
315.84	57.998	63.6895	8.936323884	55.212	51.7319	-6.72718380	11.907	12.7746	6.791602085
331.02	57.998	63.6895	8.936323884	55.212	51.7319	-6.72718380	11.907	12.7746	6.791602085
347.54	57.998	63.6895	8.936323884	55.212	51.7319	-6.72718380	11.907	12.7746	6.791602085

Table C.37 Comparison of τ_{xy} along the mid cross-section of the tube for layer 1, 2, 3 and stacking sequence is [+45/-45/0/0/45/-45] between FEM and CLPT with $\frac{b}{a} = 0.4$

	SXYLAYER 1			SXYLAYER 2			SXYLAYER 3		
ANGLE (deg)	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)2**	**Analytical Result (lb-in)2**	**Miss Match (%)2**	**FEM Result (lb-in)3**	**Analytical Result (lb-in)3**	**Miss Match (%)3**
0	53.578	40.4161	-32.5659823	57.469	71.9637	20.14168254	12.75	13.6659	6.702083288
8.35	55.456	40.4161	-37.2126454	61.904	71.9637	13.97885323	12.973	13.6659	5.070284431
20.25	55.456	40.4161	-37.2126454	61.904	71.9637	13.97885323	13.031	13.6659	4.645870378
40.9	55.456	40.4161	-37.2126454	61.904	71.9637	13.97885323	13.103	13.6659	4.119011554
47.27	55.456	40.4161	-37.2126454	61.904	71.9637	13.97885323	13.114	13.6659	4.038519234
68.4	54.89	40.4161	-35.8122134	58.975	71.9637	18.0489608	13.029	13.6659	4.660505345
90	54.923	40.4161	-35.8938640	59.011	71.9637	17.99893557	13.034	13.6659	4.623917927
111.6	54.89	40.4161	-35.8122134	58.975	71.9637	18.0489608	13.029	13.6659	4.660505345
132.73	55.456	40.4161	-37.2126454	61.904	71.9637	13.97885323	13.114	13.6659	4.038519234
139.1	55.456	40.4161	-37.2126454	61.904	71.9637	13.97885323	13.103	13.6659	4.119011554
159.75	55.456	40.4161	-37.2126454	61.904	71.9637	13.97885323	13.031	13.6659	4.645870378
171.65	55.456	40.4161	-37.2126454	61.904	71.9637	13.97885323	12.973	13.6659	5.070284431
180	53.578	40.4161	-32.5659823	57.469	71.9637	20.14168254	12.75	13.6659	6.702083288
188.35	55.456	40.4161	-37.2126454	61.904	71.9637	13.97885323	12.973	13.6659	5.070284431
200.25	55.456	40.4161	-37.2126454	61.904	71.9637	13.97885323	13.031	13.6659	4.645870378
220.9	55.456	40.4161	-37.2126454	61.904	71.9637	13.97885323	13.103	13.6659	4.119011554
227.27	55.456	40.4161	-37.2126454	61.904	71.9637	13.97885323	13.114	13.6659	4.038519234
248.4	54.89	40.4161	-35.8122134	58.975	71.9637	18.0489608	13.029	13.6659	4.660505345
270	54.923	40.4161	-35.8938640	59.011	71.9637	17.99893557	13.034	13.6659	4.623917927
291.6	54.89	40.4161	-35.8122134	58.975	71.9637	18.0489608	13.029	13.6659	4.660505345
312.73	55.456	40.4161	-37.2126454	61.904	71.9637	13.97885323	13.114	13.6659	4.038519234

Table C.37 – *Continued*

319.1	55.456	40.4161	-37.2126454	61.904	71.9637	13.97885323	13.103	13.6659	4.119011554
339.75	55.456	40.4161	-37.2126454	61.904	71.9637	13.97885323	13.031	13.6659	4.645870378
351.65	55.456	40.4161	-37.2126454	61.904	71.9637	13.97885323	12.973	13.6659	5.070284431

Table C.38 Comparison of τ_{xy} along the mid cross-section of the tube for layer 4, 5, 6 and stacking sequence is [+45/-45/0/0/45/-45] between FEM and CLPT with $\frac{b}{a} = 0.4$

	SXYLAYER 4			**SXYLAYER 5**			**SXYLAYER 6**		
ANGLE (deg)	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**
0	88.929	95.5643	6.943283214	84.381	77.6222	-8.70730280	18.488	19.1679	3.547076101
8.35	88.095	95.5643	7.815994048	83.21	77.6222	-7.19871377	17.895	19.1679	6.640790071
20.25	88.095	95.5643	7.815994048	83.21	77.6222	-7.19871377	17.895	19.1679	6.640790071
40.9	88.095	95.5643	7.815994048	83.21	77.6222	-7.19871377	17.895	19.1679	6.640790071
47.27	88.095	95.5643	7.815994048	83.21	77.6222	-7.19871377	17.895	19.1679	6.640790071
68.4	89.518	95.5643	6.326944267	85.373	77.6222	-9.98528771	18.585	19.1679	3.041021708
90	89.527	95.5643	6.317526524	85.393	77.6222	-10.0110535	18.585	19.1679	3.041021708
111.6	89.518	95.5643	6.326944267	85.373	77.6222	-9.98528771	18.585	19.1679	3.041021708
132.73	88.095	95.5643	7.815994048	83.21	77.6222	-7.19871377	17.895	19.1679	6.640790071
139.1	88.095	95.5643	7.815994048	83.21	77.6222	-7.19871377	17.895	19.1679	6.640790071
159.75	88.095	95.5643	7.815994048	83.21	77.6222	-7.19871377	17.895	19.1679	6.640790071
171.65	88.095	95.5643	7.815994048	83.21	77.6222	-7.19871377	17.895	19.1679	6.640790071
180	88.929	95.5643	6.943283214	84.381	77.6222	-8.70730280	18.488	19.1679	3.547076101
188.35	88.095	95.5643	7.815994048	84.238	77.6222	-8.52307716	17.895	19.1679	6.640790071
200.25	88.095	95.5643	7.815994048	83.21	77.6222	-7.19871377	17.895	19.1679	6.640790071
220.9	88.095	95.5643	7.815994048	83.21	77.6222	-7.19871377	17.895	19.1679	6.640790071
227.27	88.095	95.5643	7.815994048	83.21	77.6222	-7.19871377	17.895	19.1679	6.640790071

Table C.38 – *Continued*

248.4	89.518	95.5643	6.326944267	85.373	77.6222	-9.98528771	18.585	19.1679	3.041021708
270	89.527	95.5643	6.317526524	85.393	77.6222	-10.0110535	18.585	19.1679	3.041021708
291.6	89.518	95.5643	6.326944267	85.373	77.6222	-9.98528771	18.585	19.1679	3.041021708
312.73	88.095	95.5643	7.815994048	83.21	77.6222	-7.19871377	17.895	19.1679	6.640790071
319.1	88.095	95.5643	7.815994048	83.21	77.6222	-7.19871377	17.895	19.1679	6.640790071
339.75	88.095	95.5643	7.815994048	83.21	77.6222	-7.19871377	17.895	19.1679	6.640790071
351.65	88.095	95.5643	7.815994048	83.21	77.6222	-7.19871377	17.895	19.1679	6.640790071

Table C.39 Comparison of τ_{xy} along the mid cross-section of the tube for layer 1, 2, 3 and stacking sequence is [+45/-45/0/0/45/-45] between FEM and CLPT with $\frac{b}{a} = 0.2$

	SXYLAYER 1			**SXYLAYER 2**			**SXYLAYER 3**		
ANGLE (deg)	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**
0	105.82	79.5253	-33.0645719	113.68	144.6572	21.41421236	25.326	27.324	7.312252964
4.18	109.29	79.5253	-37.4279631	117.07	144.6572	19.07074103	26.02	27.324	4.772361294
10.44	111.95	79.5253	-40.7728106	119.05	144.6572	17.70198787	26.063	27.324	4.614990485
23.41	111.95	79.5253	-40.7728106	119.05	144.6572	17.70198787	26.108	27.324	4.450300102
28.42	111.95	79.5253	-40.7728106	119.05	144.6572	17.70198787	26.116	27.324	4.421021812
51.62	109.19	79.5253	-37.3022170	117.2	144.6572	18.9808734	26.009	27.324	4.812618943
90	109.24	79.5253	-37.3650901	117.25	144.6572	18.94630893	26.012	27.324	4.801639584
128.38	109.19	79.5253	-37.3022170	117.2	144.6572	18.9808734	26.009	27.324	4.812618943
151.58	111.95	79.5253	-40.7728106	119.05	144.6572	17.70198787	26.116	27.324	4.421021812
156.59	111.95	79.5253	-40.7728106	119.05	144.6572	17.70198787	26.108	27.324	4.450300102
169.56	111.95	79.5253	-40.7728106	119.05	144.6572	17.70198787	26.063	27.324	4.614990485
177.59	109.29	79.5253	-37.4279631	117.07	144.6572	19.07074103	26.02	27.324	4.772361294
180	105.82	79.5253	-33.0645719	113.68	144.6572	21.41421236	25.326	27.324	7.312252964

Table C.39 – *Continued*

184.18	109.29	79.5253	-37.4279631	117.07	144.6572	19.07074103	26.02	27.324	4.772361294
190.44	111.95	79.5253	-40.7728106	119.05	144.6572	17.70198787	26.063	27.324	4.614990485
203.41	111.95	79.5253	-40.7728106	119.05	144.6572	17.70198787	26.108	27.324	4.450300102
208.42	111.95	79.5253	-40.7728106	119.05	144.6572	17.70198787	26.116	27.324	4.421021812
231.62	109.19	79.5253	-37.3022170	117.2	144.6572	18.9808734	26.009	27.324	4.812618943
270	109.24	79.5253	-37.3650901	117.25	144.6572	18.94630893	26.012	27.324	4.801639584
308.38	109.19	79.5253	-37.3022170	117.2	144.6572	18.9808734	26.009	27.324	4.812618943
331.58	111.95	79.5253	-40.7728106	119.05	144.6572	17.70198787	26.116	27.324	4.421021812
336.59	111.95	79.5253	-40.7728106	119.05	144.6572	17.70198787	26.108	27.324	4.450300102
349.56	111.95	79.5253	-40.7728106	119.05	144.6572	17.70198787	26.063	27.324	4.614990485
355.82	109.29	79.5253	-37.4279631	117.07	144.6572	19.07074103	26.02	27.324	4.772361294

Table C.40 Comparison of τ_{xy} along the mid cross-section of the tube for layer 4, 5, 6 and stacking sequence is [+45/-45/0/0/45/-45] between FEM and CLPT with $\frac{b}{a} = 0.2$

	SXYLAYER 4			SXYLAYER 5			SXYLAYER 6		
ANGLE (deg)	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**
0	176.14	191.3314	7.939836326	167.69	154.4299	-8.58648487	36.725	38.3249	4.174570579
4.18	178.43	191.3314	6.742960121	170.43	154.4299	-10.3607526	37.105	38.3249	3.183048097
10.44	176.01	191.3314	8.007781263	167.51	154.4299	-8.46992713	36.181	38.3249	5.594013292
23.41	176.01	191.3314	8.007781263	167.51	154.4299	-8.46992713	36.181	38.3249	5.594013292
28.42	176.01	191.3314	8.007781263	167.51	154.4299	-8.46992713	36.181	38.3249	5.594013292
51.62	178.77	191.3314	6.565257976	170.4	154.4299	-10.3413263	37.143	38.3249	3.083895848
90	178.74	191.3314	6.580937577	170.37	154.4299	-10.3219001	37.13	38.3249	3.117816354
128.38	178.77	191.3314	6.565257976	170.4	154.4299	-10.3413263	37.143	38.3249	3.083895848
151.58	176.01	191.3314	8.007781263	167.51	154.4299	-8.46992713	36.181	38.3249	5.594013292

Table C.40 – *Continued*

156.59	176.01	191.3314	8.007781263	167.51	154.4299	-8.46992713	36.181	38.3249	5.594013292
169.56	176.01	191.3314	8.007781263	167.51	154.4299	-8.46992713	36.181	38.3249	5.594013292
177.59	178.43	191.3314	6.742960121	170.43	154.4299	-10.3607526	37.105	38.3249	3.183048097
180	176.14	191.3314	7.939836326	167.69	154.4299	-8.58648487	36.725	38.3249	4.174570579
184.18	178.43	191.3314	6.742960121	170.43	154.4299	-10.3607526	37.105	38.3249	3.183048097
190.44	176.01	191.3314	8.007781263	167.51	154.4299	-8.46992713	36.181	38.3249	5.594013292
203.41	176.01	191.3314	8.007781263	167.51	154.4299	-8.46992713	36.181	38.3249	5.594013292
208.42	176.01	191.3314	8.007781263	167.51	154.4299	-8.46992713	36.181	38.3249	5.594013292
231.62	178.77	191.3314	6.565257976	170.4	154.4299	-10.3413263	37.143	38.3249	3.083895848
270	178.74	191.3314	6.580937577	170.37	154.4299	-10.3219001	37.13	38.3249	3.117816354
308.38	178.77	191.3314	6.565257976	170.4	154.4299	-10.3413263	37.143	38.3249	3.083895848
331.58	176.01	191.3314	8.007781263	167.51	154.4299	-8.46992713	36.181	38.3249	5.594013292
336.59	176.01	191.3314	8.007781263	167.51	154.4299	-8.46992713	36.181	38.3249	5.594013292
349.56	176.01	191.3314	8.007781263	167.51	154.4299	-8.46992713	36.181	38.3249	5.594013292
355.82	178.43	191.3314	6.742960121	170.43	154.4299	-10.3607526	37.105	38.3249	3.183048097

Table C.41 Comparison of τ_{xy} along the mid cross-section of the tube for layer 1, 2, 3 and stacking sequence is $[\pm 45/0]_{2T}$ between FEM and CLPT with $\frac{b}{a} = 1$

	SXYLAYER 1			**SXYLAYER 2**			**SXYLAYER 3**		
ANGLE (deg)	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**
0	29.11	29.21	0.34234851	29.209	29.21	0.00342349	5.2898	5.2855	-0.0813546
20.25	28.856	29.21	1.21191373	28.939	29.21	0.92776446	5.2718	5.2855	0.2591997
42.75	28.856	29.21	1.21191373	28.939	29.21	0.92776446	5.2718	5.2855	0.2591997
65.25	28.856	29.21	1.21191373	28.939	29.21	0.92776446	5.2718	5.2855	0.2591997
69.75	28.856	29.21	1.21191373	28.939	29.21	0.92776446	5.2718	5.2855	0.2591997

Table C.41 – *Continued*

81	29.11	29.21	0.34234851	29.209	29.21	0.00342349	5.2898	5.2855	-0.0813546
90	29.11	29.21	0.34234851	29.209	29.21	0.00342349	5.2898	5.2855	-0.0813546
99	29.11	29.21	0.34234851	29.209	29.21	0.00342349	5.2898	5.2855	-0.0813546
110.25	28.856	29.21	1.21191373	28.939	29.21	0.92776446	5.2718	5.2855	0.2591997
137.25	28.856	29.21	1.21191373	28.939	29.21	0.92776446	5.2718	5.2855	0.2591997
155.75	28.856	29.21	1.21191373	28.939	29.21	0.92776446	5.2718	5.2855	0.2591997
159.75	28.856	29.21	1.21191373	28.939	29.21	0.92776446	5.2718	5.2855	0.2591997
180	29.11	29.21	0.34234851	29.209	29.21	0.00342349	5.2898	5.2855	-0.0813546
200.25	28.856	29.21	1.21191373	28.939	29.21	0.92776446	5.2718	5.2855	0.2591997
222.75	28.856	29.21	1.21191373	28.939	29.21	0.92776446	5.2718	5.2855	0.2591997
245.25	28.856	29.21	1.21191373	28.939	29.21	0.92776446	5.2718	5.2855	0.2591997
249.75	28.856	29.21	1.21191373	28.939	29.21	0.92776446	5.2718	5.2855	0.2591997
261	29.11	29.21	0.34234851	29.209	29.21	0.00342349	5.2898	5.2855	-0.0813546
270	29.11	29.21	0.34234851	29.209	29.21	0.00342349	5.2898	5.2855	-0.0813546
279	29.11	29.21	0.34234851	29.209	29.21	0.00342349	5.2898	5.2855	-0.0813546
290.25	28.856	29.21	1.21191373	28.939	29.21	0.92776446	5.2718	5.2855	0.2591997
294.75	28.856	29.21	1.21191373	28.939	29.21	0.92776446	5.2718	5.2855	0.2591997
317.25	28.856	29.21	1.21191373	28.939	29.21	0.92776446	5.2718	5.2855	0.2591997
339.75	28.856	29.21	1.21191373	28.939	29.21	0.92776446	5.2718	5.2855	0.2591997

Table C.42 Comparison of τ_{xy} along the mid cross-section of the tube for layer 4, 5, 6 and stacking sequence is $[\pm45/0]_{2T}$ between FEM and CLPT with $\frac{b}{a} = 1$

	SXYLAYER 4			**SXYLAYER 5**			**SXYLAYER 6**		
ANGLE (deg)	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**
0	5.2898	5.2855	-0.0813546	29.191	29.21	0.06504622	29.278	29.21	-0.232797

Table C.42 – *Continued*

20.25	5.2718	5.2855	0.2591997	29.487	29.21	-0.9483054	29.57	29.21	-1.2324546
42.75	5.2718	5.2855	0.2591997	29.487	29.21	-0.9483054	29.57	29.21	-1.2324546
65.25	5.2718	5.2855	0.2591997	29.487	29.21	-0.9483054	29.57	29.21	-1.2324546
69.75	5.2718	5.2855	0.2591997	29.487	29.21	-0.9483054	29.57	29.21	-1.2324546
81	5.2898	5.2855	-0.0813546	29.191	29.21	0.06504622	29.278	29.21	-0.232797
90	5.2898	5.2855	-0.0813546	29.191	29.21	0.06504622	29.278	29.21	-0.232797
99	5.2898	5.2855	-0.0813546	29.191	29.21	0.06504622	29.278	29.21	-0.232797
110.25	5.2718	5.2855	0.2591997	29.487	29.21	-0.9483054	29.57	29.21	-1.2324546
137.25	5.2718	5.2855	0.2591997	29.487	29.21	-0.9483054	29.57	29.21	-1.2324546
155.75	5.2718	5.2855	0.2591997	29.487	29.21	-0.9483054	29.57	29.21	-1.2324546
159.75	5.2718	5.2855	0.2591997	29.487	29.21	-0.9483054	29.57	29.21	-1.2324546
180	5.2898	5.2855	-0.0813546	29.191	29.21	0.06504622	29.278	29.21	-0.232797
200.25	5.2718	5.2855	0.2591997	29.487	29.21	-0.9483054	29.57	29.21	-1.2324546
222.75	5.2718	5.2855	0.2591997	29.487	29.21	-0.9483054	29.57	29.21	-1.2324546
245.25	5.2718	5.2855	0.2591997	29.487	29.21	-0.9483054	29.57	29.21	-1.2324546
249.75	5.2718	5.2855	0.2591997	29.487	29.21	-0.9483054	29.57	29.21	-1.2324546
261	5.2898	5.2855	-0.0813546	29.191	29.21	0.06504622	29.278	29.21	-0.232797
270	5.2898	5.2855	-0.0813546	29.191	29.21	0.06504622	29.278	29.21	-0.232797
279	5.2898	5.2855	-0.0813546	29.191	29.21	0.06504622	29.278	29.21	-0.232797
290.25	5.2718	5.2855	0.2591997	29.487	29.21	-0.9483054	29.57	29.21	-1.2324546
294.75	5.2718	5.2855	0.2591997	29.487	29.21	-0.9483054	29.57	29.21	-1.2324546
317.25	5.2718	5.2855	0.2591997	29.487	29.21	-0.9483054	29.57	29.21	-1.2324546
339.75	5.2718	5.2855	0.2591997	29.487	29.21	-0.9483054	29.57	29.21	-1.2324546

Table C.43 Comparison of τ_{xy} along the mid cross-section of the tube for layer 1, 2, 3 and stacking sequence is $[\pm45/0]_{2T}$ between FEM and CLPT with $\frac{b}{a} = 0.8$

	SXYLAYER 1			SXYLAYER 2			SXYLAYER 3		
ANGLE (deg)	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**
0	36.417	36.4976	0.22083644	36.53	36.4976	-0.088773	6.6152	6.6049	-0.1559448
16.432	36.183	36.4976	0.86197449	36.285	36.4976	0.58250406	6.5974	6.6049	0.11355206
34.46	36.096	36.4976	1.10034632	36.203	36.4976	0.80717636	6.5913	6.6049	0.20590774
60.03	35.997	36.4976	1.37159704	36.106	36.4976	1.07294726	6.5842	6.6049	0.31340369
65.23	35.982	36.4976	1.41269563	36.09	36.4976	1.11678576	6.5831	6.6049	0.33005799
78.8	36.356	36.4976	0.38797072	36.485	36.4976	0.03452282	6.6089	6.6049	-0.0605611
90	36.355	36.4976	0.39071062	36.482	36.4976	0.04274254	6.6086	6.6049	-0.056019
101.2	36.358	36.4976	0.3824909	36.483	36.4976	0.04000263	6.6088	6.6049	-0.0590471
114.77	35.985	36.4976	1.40447591	36.086	36.4976	1.12774539	6.5831	6.6049	0.33005799
119.97	36.001	36.4976	1.36063741	36.101	36.4976	1.08664679	6.5842	6.6049	0.31340369
143.54	36.101	36.4976	1.08664679	36.197	36.4976	0.8236158	6.5913	6.6049	0.20590774
163.57	36.187	36.4976	0.85101486	36.281	36.4976	0.59346368	6.5974	6.6049	0.11355206
180	36.417	36.4976	0.22083644	36.53	36.4976	-0.088773	6.6152	6.6049	-0.1559448
196.432	36.183	36.4976	0.86197449	36.285	36.4976	0.58250406	6.5974	6.6049	0.11355206
216.46	36.096	36.4976	1.10034632	36.203	36.4976	0.80717636	6.5913	6.6049	0.20590774
240.03	35.997	36.4976	1.37159704	36.106	36.4976	1.07294726	6.5842	6.6049	0.31340369
245.23	35.982	36.4976	1.41269563	36.09	36.4976	1.11678576	6.5831	6.6049	0.33005799
258.8	36.356	36.4976	0.38797072	36.485	36.4976	0.03452282	6.6089	6.6049	-0.0605611
270	36.355	36.4976	0.39071062	36.482	36.4976	0.04274254	6.6086	6.6049	-0.056019
281.2	36.358	36.4976	0.3824909	36.483	36.4976	0.04000263	6.6088	6.6049	-0.0590471
294.77	35.985	36.4976	1.40447591	36.086	36.4976	1.12774539	6.5831	6.6049	0.33005799

Table C.43 – *Continued*

299.97	36.001	36.4976	1.36063741	36.101	36.4976	1.08664679	6.5842	6.6049	0.31340369
323.54	36.101	36.4976	1.08664679	36.197	36.4976	0.8236158	6.5913	6.6049	0.20590774
343.57	36.187	36.4976	0.85101486	36.281	36.4976	0.59346368	6.5974	6.6049	0.11355206

Table C.44 Comparison of τ_{xy} along the mid cross-section of the tube for layer 4, 5, 6 and stacking sequence is $[\pm 45/0]_{2T}$ between FEM and CLPT with $\frac{b}{a} = 0.8$

	SXYLAYER 4			**SXYLAYER 5**			**SXYLAYER 6**		
ANGLE (deg)	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**
0	6.6152	6.6049	-0.1559448	36.469	36.4976	0.07836132	36.592	36.4976	-0.2586471
16.432	6.5974	6.6049	0.11355206	36.772	36.4976	-0.7518303	36.889	36.4976	-1.0723993
34.46	6.5913	6.6049	0.20590774	36.833	36.4976	-0.9189645	36.938	36.4976	-1.2066547
60.03	6.5842	6.6049	0.31340369	36.904	36.4976	-1.1134979	36.993	36.4976	-1.3573495
65.23	6.5831	6.6049	0.33005799	36.915	36.4976	-1.1436368	37.002	36.4976	-1.3820087
78.8	6.6089	6.6049	-0.0605611	36.498	36.4976	-0.001096	36.588	36.4976	-0.2476875
90	6.6086	6.6049	-0.056019	36.498	36.4976	-0.001096	36.588	36.4976	-0.2476875
101.2	6.6088	6.6049	-0.0590471	36.498	36.4976	-0.001096	36.588	36.4976	-0.2476875
114.77	6.5831	6.6049	0.33005799	36.915	36.4976	-1.1436368	37.002	36.4976	-1.3820087
119.97	6.5842	6.6049	0.31340369	36.904	36.4976	-1.1134979	36.993	36.4976	-1.3573495
143.54	6.5913	6.6049	0.20590774	36.833	36.4976	-0.9189645	36.938	36.4976	-1.2066547
163.57	6.5974	6.6049	0.11355206	36.772	36.4976	-0.7518303	36.889	36.4976	-1.0723993
180	6.6152	6.6049	-0.1559448	36.469	36.4976	0.07836132	36.592	36.4976	-0.2586471
196.432	6.5974	6.6049	0.11355206	36.772	36.4976	-0.7518303	36.889	36.4976	-1.0723993
216.46	6.5913	6.6049	0.20590774	36.833	36.4976	-0.9189645	36.938	36.4976	-1.2066547
240.03	6.5842	6.6049	0.31340369	36.904	36.4976	-1.1134979	36.993	36.4976	-1.3573495
245.23	6.5831	6.6049	0.33005799	36.915	36.4976	-1.1436368	37.002	36.4976	-1.3820087

Table C.44 – *Continued*

258.8	6.6089	6.6049	-0.0605611	36.498	36.4976	-0.001096	36.588	36.4976	-0.2476875
270	6.6086	6.6049	-0.056019	36.498	36.4976	-0.001096	36.588	36.4976	-0.2476875
281.2	6.6088	6.6049	-0.0590471	36.498	36.4976	-0.001096	36.588	36.4976	-0.2476875
294.77	6.5831	6.6049	0.33005799	36.915	36.4976	-1.1436368	37.002	36.4976	-1.3820087
299.97	6.5842	6.6049	0.31340369	36.904	36.4976	-1.1134979	36.993	36.4976	-1.3573495
323.54	6.5913	6.6049	0.20590774	36.833	36.4976	-0.9189645	36.938	36.4976	-1.2066547
343.57	6.5974	6.6049	0.11355206	36.772	36.4976	-0.7518303	36.889	36.4976	-1.0723993

Table C.45 Comparison of τ_{xy} along the mid cross-section of the tube for layer 1, 2, 3 and stacking sequence is $[\pm 45/0]_{2T}$ between FEM and CLPT with $\frac{b}{a} = 0.6$

	SXYLAYER 1			**SXYLAYER 2**			**SXYLAYER 3**		
ANGLE (deg)	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**
0	48.453	48.6481	0.40104341	48.634	48.6481	0.02898366	8.8048	8.8037	-0.0124947
12.46	48.267	48.6481	0.78338106	48.435	48.6481	0.43804383	8.7915	8.8037	0.1385781
28.98	48.108	48.6481	1.11021808	48.273	48.6481	0.77104758	8.7864	8.8037	0.19650829
44.16	47.925	48.6481	1.48638899	48.073	48.6481	1.18216333	8.7804	8.8037	0.26466145
58.38	47.896	48.6481	1.54600077	48.039	48.6481	1.25205301	8.7795	8.8037	0.27488442
75.21	48.52	48.6481	0.26331964	48.687	48.6481	-0.079962	8.8221	8.8037	-0.209003
90	48.522	48.6481	0.25920848	48.683	48.6481	-0.0717397	8.8223	8.8037	-0.2112748
104.79	48.524	48.6481	0.25509732	48.682	48.6481	-0.0696841	8.822	8.8037	-0.2078671
121.62	47.905	48.6481	1.52750056	48.031	48.6481	1.26849764	8.7794	8.8037	0.27602031
135.84	47.935	48.6481	1.4658332	48.063	48.6481	1.20271912	8.7804	8.8037	0.26466145
151.02	48.12	48.6481	1.08555113	48.26	48.6481	0.79777011	8.7864	8.8037	0.19650829
167.54	48.275	48.6481	0.76693643	48.426	48.6481	0.45654404	8.7914	8.8037	0.13971398
180	48.453	48.6481	0.40104341	48.634	48.6481	0.02898366	8.8048	8.8037	-0.0124947

Table C.45 – *Continued*

192.46	48.267	48.6481	0.78338106	48.435	48.6481	0.43804383	8.7915	8.8037	0.1385781
208.98	48.108	48.6481	1.11021808	48.273	48.6481	0.77104758	8.7864	8.8037	0.19650829
224.16	47.925	48.6481	1.48638899	48.073	48.6481	1.18216333	8.7804	8.8037	0.26466145
238.38	47.896	48.6481	1.54600077	48.039	48.6481	1.25205301	8.7795	8.8037	0.27488442
255.21	48.52	48.6481	0.26331964	48.687	48.6481	-0.079962	8.8221	8.8037	-0.209003
270	48.522	48.6481	0.25920848	48.683	48.6481	-0.0717397	8.8223	8.8037	-0.2112748
284.79	48.524	48.6481	0.25509732	48.682	48.6481	-0.0696841	8.822	8.8037	-0.2078671
301.62	47.905	48.6481	1.52750056	48.031	48.6481	1.26849764	8.7794	8.8037	0.27602031
315.84	47.935	48.6481	1.4658332	48.063	48.6481	1.20271912	8.7804	8.8037	0.26466145
331.02	48.12	48.6481	1.08555113	48.26	48.6481	0.79777011	8.7864	8.8037	0.19650829
347.54	48.275	48.6481	0.76693643	48.426	48.6481	0.45654404	8.7914	8.8037	0.13971398

Table C.46 Comparison of τ_{xy} along the mid cross-section of the tube for layer 4, 5, 6 and stacking sequence is $[\pm 45/0]_{2T}$ between FEM and CLPT with $\frac{b}{a} = 0.6$

	SXYLAYER 4			**SXYLAYER 5**			**SXYLAYER 6**		
ANGLE (deg)	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**
0	8.8048	8.8037	-0.0124947	48.477	48.6481	0.35170952	48.674	48.6481	-0.0532395
12.46	8.7915	8.8037	0.1385781	48.864	48.6481	-0.4437994	49.056	48.6481	-0.8384706
28.98	8.7864	8.8037	0.19650829	49.084	48.6481	-0.8960268	49.244	48.6481	-1.2249194
44.16	8.7804	8.8037	0.26466145	49.348	48.6481	-1.4386996	49.467	48.6481	-1.6833134
58.38	8.7795	8.8037	0.27488442	49.392	48.6481	-1.529145	49.503	48.6481	-1.7573143
75.21	8.8221	8.8037	-0.209003	48.761	48.6481	-0.2320748	48.875	48.6481	-0.4664108
90	8.8223	8.8037	-0.2112748	48.768	48.6481	-0.2464639	48.879	48.6481	-0.4746331
104.79	8.822	8.8037	-0.2078671	48.761	48.6481	-0.2320748	48.875	48.6481	-0.4664108
121.62	8.7794	8.8037	0.27602031	49.392	48.6481	-1.529145	49.503	48.6481	-1.7573143

Table C.46 – *Continued*

135.84	8.7804	8.8037	0.26466145	49.348	48.6481	-1.4386996	49.467	48.6481	-1.6833134
151.02	8.7864	8.8037	0.19650829	49.084	48.6481	-0.8960268	49.244	48.6481	-1.2249194
167.54	8.7914	8.8037	0.13971398	48.864	48.6481	-0.4437994	49.056	48.6481	-0.8384706
180	8.8048	8.8037	-0.0124947	48.477	48.6481	0.35170952	48.674	48.6481	-0.0532395
192.46	8.7915	8.8037	0.1385781	48.864	48.6481	-0.4437994	49.056	48.6481	-0.8384706
208.98	8.7864	8.8037	0.19650829	49.084	48.6481	-0.8960268	49.244	48.6481	-1.2249194
224.16	8.7804	8.8037	0.26466145	49.348	48.6481	-1.4386996	49.467	48.6481	-1.6833134
238.38	8.7795	8.8037	0.27488442	49.392	48.6481	-1.529145	49.503	48.6481	-1.7573143
255.21	8.8221	8.8037	-0.209003	48.761	48.6481	-0.2320748	48.875	48.6481	-0.4664108
270	8.8223	8.8037	-0.2112748	48.768	48.6481	-0.2464639	48.879	48.6481	-0.4746331
284.79	8.822	8.8037	-0.2078671	48.761	48.6481	-0.2320748	48.875	48.6481	-0.4664108
301.62	8.7794	8.8037	0.27602031	49.392	48.6481	-1.529145	49.503	48.6481	-1.7573143
315.84	8.7804	8.8037	0.26466145	49.348	48.6481	-1.4386996	49.467	48.6481	-1.6833134
331.02	8.7864	8.8037	0.19650829	49.084	48.6481	-0.8960268	49.244	48.6481	-1.2249194
347.54	8.7914	8.8037	0.13971398	48.864	48.6481	-0.4437994	49.056	48.6481	-0.8384706

Table C.47 Comparison of τ_{xy} along the mid cross-section of the tube for layer 1, 2, 3 and stacking sequence is $[\pm 45/0]_{2T}$ between FEM and CLPT with $\frac{b}{a} = 0.4$

	SXYLAYER 1			**SXYLAYER 2**			**SXYLAYER 3**		
ANGLE (deg)	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**
0	72.3	72.995	0.95212001	72.702	72.995	0.40139736	13.16	13.21	0.37850114
8.35	72.275	72.995	0.98636893	72.633	72.995	0.49592438	13.166	13.21	0.333081
20.25	71.966	72.995	1.40968559	72.28	72.995	0.97951915	13.166	13.21	0.333081
40.9	71.683	72.995	1.79738338	71.931	72.995	1.45763408	13.173	13.21	0.28009084
47.27	71.643	72.995	1.85218166	71.878	72.995	1.5302418	13.175	13.21	0.26495079

Table C.47 – *Continued*

68.4	72.882	72.995	0.15480512	73.152	72.995	-0.2150832	13.258	13.21	-0.3633611
90	72.893	72.995	0.1397356	73.155	72.995	-0.2191931	13.26	13.21	-0.3785011
111.6	72.886	72.995	0.1493253	73.148	72.995	-0.2096034	13.258	13.21	-0.3633611
132.73	71.652	72.995	1.83985204	71.87	72.995	1.54120145	13.175	13.21	0.26495079
139.1	71.694	72.995	1.78231386	71.922	72.995	1.4699637	13.173	13.21	0.28009084
159.75	71.98	72.995	1.3905062	72.268	72.995	0.99595863	13.166	13.21	0.333081
171.65	72.283	72.995	0.97540927	72.626	72.995	0.50551408	13.166	13.21	0.333081
180	72.3	72.995	0.95212001	72.702	72.995	0.40139736	13.16	13.21	0.37850114
188.35	72.275	72.995	0.98636893	72.633	72.995	0.49592438	13.166	13.21	0.333081
200.25	71.966	72.995	1.40968559	72.28	72.995	0.97951915	13.166	13.21	0.333081
220.9	71.683	72.995	1.79738338	71.931	72.995	1.45763408	13.173	13.21	0.28009084
227.27	71.643	72.995	1.85218166	71.878	72.995	1.5302418	13.175	13.21	0.26495079
248.4	72.882	72.995	0.15480512	73.152	72.995	-0.2150832	13.258	13.21	-0.3633611
270	72.893	72.995	0.1397356	73.155	72.995	-0.2191931	13.26	13.21	-0.3785011
291.6	72.886	72.995	0.1493253	73.148	72.995	-0.2096034	13.258	13.21	-0.3633611
312.73	71.652	72.995	1.83985204	71.87	72.995	1.54120145	13.175	13.21	0.26495079
319.1	71.694	72.995	1.78231386	71.922	72.995	1.4699637	13.173	13.21	0.28009084
339.75	71.98	72.995	1.3905062	72.268	72.995	0.99595863	13.166	13.21	0.333081
351.65	72.283	72.995	0.97540927	72.626	72.995	0.50551408	13.166	13.21	0.333081

Table C.48 Comparison of τ_{xy} along the mid cross-section of the tube for layer 4, 5, 6 and stacking sequence is $[\pm 45/0]_{2T}$ between FEM and CLPT with $\frac{b}{a} = 0.4$

	SXYLAYER 4			**SXYLAYER 5**			**SXYLAYER 6**		
ANGLE (deg)	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**
0	13.16	13.21	0.37850114	72.322	72.995	0.92198096	72.653	72.995	0.46852524

Table C.48 – *Continued*

8.35	13.166	13.21	0.333081	73.058	72.995	-0.0863073	73.399	72.995	-0.5534626
20.25	13.166	13.21	0.333081	73.659	72.995	-0.9096513	73.958	72.995	-1.3192684
40.9	13.173	13.21	0.28009084	74.355	72.995	-1.8631413	74.599	72.995	-2.1974108
47.27	13.175	13.21	0.26495079	74.467	72.995	-2.0165765	74.702	72.995	-2.3385163
68.4	13.258	13.21	-0.3633611	73.314	72.995	-0.4370162	73.568	72.995	-0.7849853
90	13.26	13.21	-0.3785011	73.338	72.995	-0.4698952	73.588	72.995	-0.8123844
111.6	13.258	13.21	-0.3633611	73.314	72.995	-0.4370162	73.568	72.995	-0.7849853
132.73	13.175	13.21	0.26495079	74.467	72.995	-2.0165765	74.702	72.995	-2.3385163
139.1	13.173	13.21	0.28009084	74.355	72.995	-1.8631413	74.599	72.995	-2.1974108
159.75	13.166	13.21	0.333081	73.659	72.995	-0.9096513	73.958	72.995	-1.3192684
171.65	13.166	13.21	0.333081	73.058	72.995	-0.0863073	73.399	72.995	-0.5534626
180	13.16	13.21	0.37850114	72.322	72.995	0.92198096	72.653	72.995	0.46852524
188.35	13.166	13.21	0.333081	73.058	72.995	-0.0863073	73.399	72.995	-0.5534626
200.25	13.166	13.21	0.333081	73.659	72.995	-0.9096513	73.958	72.995	-1.3192684
220.9	13.173	13.21	0.28009084	74.355	72.995	-1.8631413	74.599	72.995	-2.1974108
227.27	13.175	13.21	0.26495079	74.467	72.995	-2.0165765	74.702	72.995	-2.3385163
248.4	13.258	13.21	-0.3633611	73.314	72.995	-0.4370162	73.568	72.995	-0.7849853
270	13.26	13.21	-0.3785011	73.338	72.995	-0.4698952	73.588	72.995	-0.8123844
291.6	13.258	13.21	-0.3633611	73.314	72.995	-0.4370162	73.568	72.995	-0.7849853
312.73	13.175	13.21	0.26495079	74.467	72.995	-2.0165765	74.702	72.995	-2.3385163
319.1	13.173	13.21	0.28009084	74.355	72.995	-1.8631413	74.599	72.995	-2.1974108
339.75	13.166	13.21	0.333081	73.659	72.995	-0.9096513	73.958	72.995	-1.3192684
351.65	13.166	13.21	0.333081	73.058	72.995	-0.0863073	73.399	72.995	-0.5534626

Table C.49 Comparison of τ_{xy} along the mid cross-section of the tube for layer 1, 2, 3 and stacking sequence is $[\pm45/0]_{2T}$ between FEM and CLPT with $\frac{b}{a} = 0.2$

	SXYLAYER 1			**SXYLAYER 2**			**SXYLAYER 3**		
ANGLE (deg)	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**
0	142.5	145.95	2.36382323	143.74	145.95	1.5142172	26.046	26.412	1.38573376
4.18	144.23	145.95	1.17848578	145.32	145.95	0.43165468	26.323	26.412	0.33696804
10.44	142.53	145.95	2.34326824	143.51	145.95	1.67180541	26.254	26.412	0.59821293
23.41	140.98	145.95	3.40527578	141.89	145.95	2.78177458	26.205	26.412	0.78373467
28.42	140.77	145.95	3.54916067	141.66	145.95	2.9393628	26.199	26.412	0.80645161
51.62	144.81	145.95	0.78108941	145.87	145.95	0.05481329	26.435	26.412	-0.0870816
90	144.8	145.95	0.78794108	145.86	145.95	0.06166495	26.436	26.412	-0.0908678
128.38	144.81	145.95	0.78108941	145.88	145.95	0.04796163	26.435	26.412	-0.0870816
151.58	140.75	145.95	3.56286399	141.68	145.95	2.92565947	26.199	26.412	0.80645161
156.59	140.97	145.95	3.41212744	141.91	145.95	2.76807126	26.205	26.412	0.78373467
169.56	142.51	145.95	2.35697157	143.54	145.95	1.65125043	26.255	26.412	0.59442678
177.59	144.22	145.95	1.18533744	145.34	145.95	0.41795135	26.324	26.412	0.33318189
180	142.5	145.95	2.36382323	143.74	145.95	1.5142172	26.046	26.412	1.38573376
184.18	144.23	145.95	1.17848578	145.32	145.95	0.43165468	26.323	26.412	0.33696804
190.44	142.53	145.95	2.34326824	143.51	145.95	1.67180541	26.254	26.412	0.59821293
203.41	140.98	145.95	3.40527578	141.89	145.95	2.78177458	26.205	26.412	0.78373467
208.42	140.77	145.95	3.54916067	141.66	145.95	2.9393628	26.199	26.412	0.80645161
231.62	144.81	145.95	0.78108941	145.87	145.95	0.05481329	26.435	26.412	-0.0870816
270	144.8	145.95	0.78794108	145.86	145.95	0.06166495	26.436	26.412	-0.0908678
308.38	144.81	145.95	0.78108941	145.88	145.95	0.04796163	26.435	26.412	-0.0870816
331.58	140.75	145.95	3.56286399	141.68	145.95	2.92565947	26.199	26.412	0.80645161

Table C.49 – *Continued*

336.59	140.97	145.95	3.41212744	141.91	145.95	2.76807126	26.205	26.412	0.78373467
349.56	142.51	145.95	2.35697157	143.54	145.95	1.65125043	26.255	26.412	0.59442678
355.82	144.22	145.95	1.18533744	145.34	145.95	0.41795135	26.324	26.412	0.33318189

Table C.50 Comparison of τ_{xy} along the mid cross-section of the tube for layer 4, 5, 6 and stacking sequence is [±45/0]$_{2T}$ between FEM and CLPT with $\frac{b}{a} = 0.2$

	SXYLAYER 4			SXYLAYER 5			SXYLAYER 6		
ANGLE (deg)	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**	**FEM Result (lb-in)**	**Analytical Result (lb-in)**	**Miss Match (%)**
0	26.046	26.412	1.38573376	142.5	145.95	2.36382323	143.38	145.95	1.76087701
4.18	26.323	26.412	0.33696804	146.03	145.95	-0.0548133	147.02	145.95	-0.7331278
10.44	26.254	26.412	0.59821293	148.06	145.95	-1.4457006	149.02	145.95	-2.1034601
23.41	26.205	26.412	0.78373467	150.06	145.95	-2.8160329	151.02	145.95	-3.4737924
28.42	26.199	26.412	0.80645161	150.36	145.95	-3.0215827	151.32	145.95	-3.6793422
51.62	26.435	26.412	-0.0870816	146.33	145.95	-0.2603631	147.43	145.95	-1.0140459
90	26.436	26.412	-0.0908678	146.38	145.95	-0.2946214	147.48	145.95	-1.0483042
128.38	26.435	26.412	-0.0870816	146.33	145.95	-0.2603631	147.43	145.95	-1.0140459
151.58	26.199	26.412	0.80645161	150.36	145.95	-3.0215827	151.32	145.95	-3.6793422
156.59	26.205	26.412	0.78373467	150.06	145.95	-2.8160329	151.02	145.95	-3.4737924
169.56	26.255	26.412	0.59442678	148.06	145.95	-1.4457006	149.02	145.95	-2.1034601
177.59	26.324	26.412	0.33318189	146.03	145.95	-0.0548133	147.02	145.95	-0.7331278
180	26.046	26.412	1.38573376	142.5	145.95	2.36382323	143.38	145.95	1.76087701
184.18	26.323	26.412	0.33696804	146.03	145.95	-0.0548133	147.02	145.95	-0.7331278
190.44	26.254	26.412	0.59821293	148.06	145.95	-1.4457006	149.02	145.95	-2.1034601
203.41	26.205	26.412	0.78373467	150.06	145.95	-2.8160329	151.02	145.95	-3.4737924
208.42	26.199	26.412	0.80645161	150.36	145.95	-3.0215827	151.32	145.95	-3.6793422

Table C.50 – *Continued*

231.62	26.435	26.412	-0.0870816	146.33	145.95	-0.2603631	147.43	145.95	-1.0140459
270	26.436	26.412	-0.0908678	146.38	145.95	-0.2946214	147.48	145.95	-1.0483042
308.38	26.435	26.412	-0.0870816	146.33	145.95	-0.2603631	147.43	145.95	-1.0140459
331.58	26.199	26.412	0.80645161	150.36	145.95	-3.0215827	151.32	145.95	-3.6793422
336.59	26.205	26.412	0.78373467	150.06	145.95	-2.8160329	151.02	145.95	-3.4737924
349.56	26.255	26.412	0.59442678	148.06	145.95	-1.4457006	149.02	145.95	-2.1034601
355.82	26.324	26.412	0.33318189	146.03	145.95	-0.0548133	147.02	145.95	-0.7331278

REFERENCES

[1] Lekhnitskii, S.G., Anisotropic Plates (translated from second Russian edition by Tsai,S.W. and Cheron, T.) Gordon and Breach Science Publishers, New York, 1968.

[2] J.M. Whitney. "On the Use of Shell Theory for Determining Stress in Composite Cylinders", Journal of Composite Material, Volume 5, Issue 3, July 1971, Pages 340-353

[3] J.Loughlan, M. and M. Ata., "The behavior of open and closed section carbon fiber composite beams subjected to constrained torsion", Composite Structures, Volume 38, Issue. 1-4, 1997, Pages. 631-647

[4] Liu, R.H., (1996). "Non Linear Buckling of Symmetrically Laminated, Cylindrically Orthotropic, Shallow Conical Shells considering Shear", International Journal of Non-Linear Mechanics, Volume 31, Issue 1, January 1996, Pages. 89-99

[5] Chan, W. S. and Demirhan, K. C., (1997). "A Simple Closed-Form Solution of Bending Stiffness for Laminated Composite Tubes", Journal of reinforced plastics and composites, Volume 19, Issue 4, 2000, Pages. 278-291

[6] Chouchaoui, C.S. and Ochoa, O.O., "Similitude study for a laminated cylindrical tube under tensile, torsion, bending, internal and external pressure. Part I: governing equations", Composite Structures 44, 1999, Pages.221-229

[7] Tarn, J. Q. and Wang, Y. M., (2000). "Laminated composite tubes under extension, torsion, bending, shearing and pressuring: a state space approach", International Journal of Solid and Structures, Volume 38, 2001, Pages 9053-9075

[8] Lin, C.Y. and Chan, W.S., (2003). "A simple analytical method for analyzing laminated composite elliptical tubes", Proceedings of 17th technical conference, American Society of composites, October 2002.

[9] Correia, P. I. F., Soares, M. C.M. and Herskovits, J., (2003). "Analysis of Laminated Conical Shell Structures Using Higher Order Models", Composite Structures, Volume 62, Issue 3, 2003, Pages. 383-390

[10] Rao, C. S., (2007). Analysis of Tapered Laminated Composite Tubes under Tension and Torsion, Master's Thesis, University of Texas at Arlington, April 2007

[11] Lawrence, K. L., ANSYS© Tutorial Release 11.0

[12] MATLAB 2010a User Manual.

[13] ANSYS V.11 User Manual

BIOGRAPHICAL INFORMATION

Thana Chomtid was born in Bangkok, Thailand, in March 1984. He was study at Phadungsit Phittaya School for kindergarten. He moved to Saint John when he was grade 1 and smoved again to Samsem Vitayalai Scholl at 7grade. He finished grade 12 from Samsem Witayalai Scholl in Bangkok, Thailand. He pursued and received his Bachelor Degree in Aerospace Engineering from King Mongkut's University of Technology North Bangkok, Bangkok, Thailand, in March 2007. In 2008, he continued his Master Degree in Aerospace Engineering at The University of Texas at Arlington, Texas, USA.