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THERMAL STRESSES IN A LONG IN-HOMOGENEOUS CYLINDER WITH VARIABLE ELASTIC CONSTANTS, THERMAL CONDUCTIVITY AND THERMAL CO-EFFICIENT

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Abstract:

The object of this paper is to study the thermal stresses in a long in-homogeneous aelotropic cylinder with the variable thermal conductivity of the material varies as m^{th} power of the radial distance, the elastic constants and the coefficients of thermal expansion of the material vary as n^{th} power of the redial distance.

Keywords and phrases : *the thermal stress, aelotropic cylinder, thermal expansion, redial distance.*

বিমূর্ত সার *(Bengali version of the Abstract)*

এই পত্রে দীর্ঘ অসমদৈশিক বেলন (Cylinder)-এ তাপজ পীড়ণকে অনুসন্ধান করা হয়েছে যখন ইহা বস্তুর তাপ পরিবাহিতা অরীয় (ব্যাসার্ধ) দূরত্বের m-তম ঘাতের সূচকীয় ভেদে থাকে এবং বস্তুর স্থিতিস্থাপক ধ্রুবক এবং তাপজ প্রসারণ গুণাঙ্ক অরীয় দূরত্বের n-তম ঘাতের সূচকীয় ভেদে থাকে। অরীয় পীড়ণ এবং হূপ পীড়ণ (Hoop Stress)-এর বিক্ষেপকে গণনা করা হয়েছে এবং ইহা তালিকাকারে এবং লেখচিত্রের সাহায্যে দেখানো হয়েছে।

1. Introduction :

For past some years an intensive attention had been paid to the determination of thermal stresses in isotropic cylinders subject to internal heat generation due to axisymmetric radiation.

Mollah[5] (1989) obtained the thermal stresses in the case of an in-homogeneous aelotropic cylinder subject to γ-ray heating, where the co-efficient of thermal expansion, thermal conductivity and the elastic constants vary linearly as the radial distance.

De and Choudhury [2] (2009) solved the same problem where the thermal conductivity of the material varies as linearly of the radial distance, the coefficients of thermal expansion and elastic constants vary as the n^{th} power of the redial distance.

. The aim of this paper is to extend the previous works. In this paper the thermal stresses in the case of an in-homogeneous transversely isotropic long hollow cylinder is obtained, the outer curved surface of which is perfectly insulated and the source of generation of heat being due to γ-ray radiation. For the non homogeneity of the material it is assumed that the elastic constants and the co-efficient of thermal expansion vary as n^{th} power of the radial distance and the thermal conductivity of the material varies as m^{th} power of the radial distance.

Finally the authors have shown numerically and graphically, for the material magnesium that the Radial stresses on the inner boundary gradually increase for $\mu = 10$ and gradually decrease for $\mu = 20,30$. The hoop stresses on the inner boundary gradually increase and reaches to a maximum and than gradually decrease as the thickness of the cylinder gradually increases.

2. Formulation and Solution of the problem, distribution of temperature:

We use the cylindrical co-ordinates and take the z axis coinciding with the axis of the cylinder. Let the temperature be symmetrical about the axis of the cylinder and be independent of axial co-ordinate. If H denotes the rate at which heat is generated in the vessel, we have the following law vide [1]:

$$H = H_i e^{-\mu(r-a)} \tag{1}$$

where

H_i = heat generation rate on the inside wall of the cylinder, a =inner radius and μ = the absorption coefficient for $\gamma - ray$ energy.

For the present problem, the temperature T satisfies the conductivity equation vide[6]:

$$K\left(\frac{d^2T}{dr^2}+\frac{1}{r}\frac{dT}{dr}\right)+\frac{dK}{dr}\frac{dT}{dr}=H_i e^{-\mu(r-a)} \tag{2}$$

where K=thermal conductivity of the material.

For non-homogeneity of the material we assume:

$$K = K_0 r^m \tag{3}$$

where K_0 is a non-zero positive constant.

Using (2) and (3) we obtain:

$$r^m \frac{d^2T}{dr^2} + (m+1)\, r^{m-1}\frac{dT}{dr} = \frac{H_i}{K_0} e^{-\mu(r-a)} \tag{4}$$

The outer wall being insulated and the inner wall being kept at a constant temperature, the boundary conditions are:

$$\left.\begin{array}{llll} & T = T_i & on & r = a \\ and & \dfrac{dT}{dr} = 0 & on & r = b \end{array}\right\} \tag{5}$$

The general solution of equation (4) is:

$$T = B + \frac{A}{r^m} + \frac{H_i e^{\mu a}}{\mu^2 K_0}\left[\sum_{\substack{p=0\\p\neq m}}^{\infty}\frac{(-1)^p \mu^p (p-1) r^{p-m}}{p!(p-m)} + \frac{(-1)^m \mu^m (m-1)\log(r)}{m!}\right] \tag{6}$$

where A and B are constants.

Using (5) in (6) we get:

$$T = B + \frac{A}{r^m} + \sum_{\substack{p=0\\p\neq m}}^{\infty} L_p r^{p-m} + K_m \log(r) \tag{7}$$

where

$$A = -\frac{H_i e^{-\mu(b-a)}(b\mu+1)}{mK_0\mu^2}$$

$$B = T_i + \frac{H_i e^{-\mu(b-a)}(b\mu+1)}{mK_0\mu^2 a^m} +$$

$$\frac{H_i e^{\mu a}}{\mu^2 K_0}\left[\sum_{\substack{p=0\\p\neq m}}^{\infty}\frac{(-1)^{p-1}\mu^p(p-1)a^{p-m}}{p!(p-m)} + \frac{(-1)^{m-1}\mu^m(m-1)\log(a)}{m!}\right] \tag{8}$$

$$L_p = \frac{(-1)^p H_i e^{\mu a}\mu^{p-2}}{p!(p-m)K_0} \quad \text{and} \quad K_m = \frac{(-1)^m H_i e^{\mu a}\mu^{m-2}(m-1)}{m!K_0}$$

3. Stress distribution:

We assume that the axial displacement is zero throughout so that considering the axially symmetric character of the problem, the non vanishing components of stress tensors are σ_{rr}, $\sigma_{\theta\theta}$, σ_{zz} and σ_{rz}.

Thus the stress-strain relations for transversely isotopic materials are given by vide[7]:

$$\begin{aligned}
\sigma_{rr} &= c'_{11}e_{rr} + c'_{12}e_{\theta\theta} + c'_{13}e_{zz} - b'_1 T \\
\sigma_{\theta\theta} &= c'_{12}e_{rr} + c'_{11}e_{\theta\theta} + c'_{13}e_{zz} - b'_1 T \\
\sigma_{zz} &= c'_{13}e_{rr} + c'_{13}e_{\theta\theta} + c'_{33}e_{zz} - b'_2 T \\
\sigma_{rz} &= c'_{44}e_{rz}
\end{aligned} \tag{9}$$

where $b'_1 = \left(c'_{11} - c'_{12}\right)\alpha'_1 + c'_{13}\alpha'_2$ and $b'_2 = 2c'_{13}\alpha'_1 + c'_{33}\alpha'_2$ and c'_{ij} are elastic constants and functions of r. T is the temperature at a point (r,θ,z) and α'_1 and α'_2 are the coefficients of thermal expansion along and perpendicular to the z-axis, respectively.

Considering the axisymmetric character of the problem, the strain components are given by:

$$e_{rr} = \frac{\partial u}{\partial r},\quad e_{\theta\theta} = \frac{u}{r},\quad e_{zz} = \frac{\partial w}{\partial z},\quad e_{rz} = \frac{\partial u}{\partial z} + \frac{\partial w}{\partial r}$$

where

$u_r = u,\ u_\theta = 0,\ u_z = w$.

Assuming u to be dependent on r alone and w =0, the above components reduce to:

$$e_{rr}=\frac{du}{dr},\ \ e_{\theta\theta}=\frac{u}{r},\ \ e_{zz}=0,\ \ e_{rz}=0 \tag{10}$$

For non-homogeneity of the material we assume:

$$c_{ij}^{/}=c_{ij}r^{n}, \alpha_i^{/}=\alpha_i r^{n},\ n\neq 0 \tag{11}$$

where c_{ij} and α_i are non-zero positive constants.

The relations (9) with (10) and (11) reduce to:

$$\begin{aligned}
\sigma_{rr} &= c_{11}r^{n}\frac{du}{dr}+c_{12}r^{n-1}u-b_1 r^{2n}T \\
\sigma_{\theta\theta} &= c_{12}r^{n}\frac{du}{dr}+c_{11}r^{n-1}u-b_1 r^{2n}T \\
\sigma_{zz} &= c_{13}r^{n}\frac{du}{dr}+c_{13}r^{n-1}u-b_2 r^{2n}T \\
\sigma_{rz} &= 0
\end{aligned} \tag{12}$$

where

$$b_1=(c_{11}+c_{12})\alpha_1+c_{13}\alpha_2 \qquad\qquad b_2=2c_{13}\alpha_1+c_{33}\alpha_2 \tag{13}$$

The stress equations of equilibrium in absence of the body forces are (vide Timoshenko and Goodier [8]):

$$\left.\begin{aligned}
\frac{\partial\sigma_{rr}}{\partial r}+\frac{\partial\sigma_{rz}}{\partial z}+\frac{\sigma_{rr}-\sigma_{\theta\theta}}{r}=0,\\
\frac{\partial\sigma_{rz}}{\partial r}+\frac{\partial\sigma_{zz}}{\partial z}+\frac{\sigma_{rz}}{r}=0,
\end{aligned}\right\} \tag{14}$$

The second equation of (14) automatically holds and the first, by (12) and (7) becomes:

$$\begin{aligned}
&r^2\frac{d^2u}{dr^2}+(n+1)r\frac{du}{dr}+(n\frac{c_{12}}{c_{11}}-1)u= \\
&\frac{b_1}{c_{11}}\left[(2n-m)Ar^{n-m+1}+(2nB+K_m)r^{n+1}+2nK_m r^{n+1}\log(r)+\sum_{\substack{p=0\\p\neq m}}^{\infty}(2n+p-m)L_p r^{p+n-m+1}\right]
\end{aligned} \tag{15}$$

The complementary function of the equation (15) is $C_1r^{\beta_1}+C_2r^{\beta_2}$

where

$$\beta_1 = \frac{-n+\sqrt{4+n^2-4n\frac{c_{11}}{c_{12}}}}{2}, \beta_2 = \frac{-n-\sqrt{4+n^2-4n\frac{c_{11}}{c_{12}}}}{2}$$

and $\beta_1 + \beta_2 = -n$.

The particular integral of equation (15) is

$$K_1 r^{n-m+1} + K_2 r^{n+1} + E_{m,n} r^{n+1}\log(r) + \sum_{\substack{p=0 \\ p\neq m}}^{\infty} B_p r^{p+n-m+1}$$

where

$$K_1 = \frac{(2n-m)b_1 A}{c_{11}(n-m+1-\beta_1)(n-m+1-\beta_2)}$$

$$K_2 = \frac{b_1}{c_{11}(n+1-\beta_1)(n+1-\beta_2)}\left[2nB + K_m + \frac{2nK_m}{\beta_1 - n - 1} + \frac{2nK_m}{\beta_2 - n - 1}\right]$$

$$E_{m,n} = \frac{2nb_1 K_m}{c_{11}(n+1-\beta_1)(n+1-\beta_2)}$$

$$B_p = \frac{(2n+p-m)b_1 L_p}{c_{11}(p+n-m+1-\beta_1)(p+n-m+1-\beta_2)}$$

The general solution of equation (15) is:

$$u = C_1 r^{\beta_1} + C_2 r^{\beta_2} + K_1 r^{n-m+1} + K_2 r^{n+1} + E_{m,n} r^{n+1}\log(r) + \sum_{\substack{p=0 \\ p\neq m}}^{\infty} B_p r^{p+n-m+1} \qquad (16)$$

In equation (16) C_1 and C_2 are constants.

Thus the stresses as calculated from (12) are:

$$\begin{aligned}\sigma_{rr} =& (c_{11}\beta_1 + c_{12})C_1 r^{n+\beta_1-1} + (c_{11}\beta_2 + c_{12})C_2 r^{n+\beta_2-1} + (c_{11}K_1(n-m+1) + c_{12}K_1 - b_1 A)r^{2n-m} + \\ & ((n+1)c_{11}K_2 + c_{11}E_{m,n} + c_{12}K_2 - b_1 B)r^{2n} + ((n+1)c_{11}E_{m,n} + c_{12}E_{m,n} - b_1 K_m)r^{2n}\log(r) + \\ & \sum_{\substack{p=0 \\ p\neq m}}^{\infty}\left[B_p(p+n-m+1)c_{11} + c_{12}B_p - b_1 L_p\right]r^{p+2n-m}\end{aligned} \qquad (17a)$$

$$\sigma_{\theta\theta}=(c_{12}\beta_1+c_{11})C_1r^{n+\beta_1-1}+(c_{12}\beta_2+c_{11})C_2r^{n+\beta_2-1}+(c_{12}K_1(n-m+1)+c_{11}K_1-b_1A)r^{2n-m}+$$
$$((n+1)c_{12}K_2+c_{12}E_{m,n}+c_{11}K_2-b_1B)r^{2n}+((n+1)c_{12}E_{m,n}+c_{11}E_{m,n}-b_1K_m)r^{2n}\log(r)+ \qquad (17b)$$
$$\sum_{\substack{p=0\\p\neq m}}^{\infty}\left[((p+n-m+1)c_{12}+c_{11})B_p-b_1L_p\right].r^{p+2n-m}$$

$$\sigma_{zz}=(c_{13}\beta_1+c_{13})C_1r^{n+\beta_1-1}+(c_{13}\beta_2+c_{13})C_2r^{n+\beta_2-1}+(c_{13}K_1(n-m+2)-b_2A)r^{2n-m}+$$
$$((n+2)c_{13}K_2+c_{13}E_{m,n}-b_2B)r^{2n}+((n+2)c_{13}E_{m,n}-b_2K_m)r^{2n}\log(r)+ \qquad (17c)$$
$$\sum_{\substack{p=0\\p\neq m}}^{\infty}\left[B_p(p+n-m+2)c_{13}-b_1L_p\right].r^{p+2n-m}$$

A distribution of normal force according to (17) is required to be applied at the ends of the cylinder just to maintain $w=0$ throughout. Let us suppose axial stress $\sigma_{zz}=c_1$ (constant) on the system such that choosing c_1 properly, we can make the resultant forces on the ends zero. According to Saint-Venant's Principle, such a distribution produces local effect only at the ends.

Due to superposition of the uniform axial stress c_1, σ_{rr} and $\sigma_{\theta\theta}$ will be undisturbed in value, while u is effected. A term c_1/c_{13} should be added to the expression of u in (16). The question of displacements being set aside, we set the boundary conditions to determine the constants C_1 and C_2 for our problem. In this case:

$$\sigma_{rr}=0 \qquad on \quad r=a \quad and \quad r=b \qquad (18)$$

Using the boundary conditions (18) we get:

$$C_1=\frac{F_2(a)F_3(b)-F_2(b)F_3(a)}{F_1(a)F_2(b)-F_1(b)F_2(a)} \quad \text{and} \quad C_2=\frac{F_1(b)F_3(a)-F_1(a)F_3(b)}{F_1(a)F_2(b)-F_1(b)F_2(a)} \qquad (19)$$

where,

$$F_1(r)=(c_{11}\beta_1+c_{12})r^{n+\beta_1-1} \quad , \quad F_2(r)=(c_{11}\beta_2+c_{12})r^{n+\beta_2-1}$$

$$F_3(r)=(c_{11}K_1(n-m+1)+c_{12}K_1-b_1A)r^{2n-m}+((n+1)c_{11}K_2+c_{11}E_{m,n}+c_{12}K_2-b_1B)r^{2n}+$$
$$((n+1)c_{11}E_{m,n}+c_{12}E_{m,n}-b_1K_m)r^{2n}\log(r)+\sum_{\substack{p=0\\p\neq m}}^{\infty}\left[B_p(p+n-m+1)c_{11}+c_{12}B_p-b_1L_p\right].r^{p+2n-m}$$

Substituting the values of C_1 and C_2 we get the stress components as followings:

$$\sigma_{rr} = \frac{F_2(a)F_3(b) - F_2(b)F_3(a)}{F_1(a)F_2(b) - F_1(b)F_2(a)} F_1(r) + \frac{F_1(b)F_3(a) - F_1(a)F_3(b)}{F_1(a)F_2(b) - F_1(b)F_2(a)} F_2(r) + F_3(r) \qquad (20)$$

$$\sigma_{\theta\theta} = \frac{F_2(a)F_3(b) - F_2(b)F_3(a)}{F_1(a)F_2(b) - F_1(b)F_2(a)} F_4(r) + \frac{F_1(b)F_3(a) - F_1(a)F_3(b)}{F_1(a)F_2(b) - F_1(b)F_2(a)} F_5(r) + F_6(r) \qquad (21)$$

$$\sigma_{zz} = \frac{F_2(a)F_3(b) - F_2(b)F_3(a)}{F_1(a)F_2(b) - F_1(b)F_2(a)} F_7(r) + \frac{F_1(b)F_3(a) - F_1(a)F_3(b)}{F_1(a)F_2(b) - F_1(b)F_2(a)} F_8(r) + F_9(r) \qquad (22)$$

where,

$$F_4(r) = (c_{12}\beta_1 + c_{11})r^{n+\beta_1-1}\ ,\ F_5(r) = (c_{12}\beta_2 + c_{11})r^{n+\beta_2-1}$$

$$F_6(r) = (c_{12}K_1(n-m+1) + c_{11}K_1 - b_1A)r^{2n-m} + ((n+1)c_{12}K_2 + c_{12}E_{m,n} + c_{11}K_2 - b_1B)r^{2n} +$$
$$((n+1)c_{12}E_{m,n} + c_{11}E_{m,n} - b_1K_m)r^{2n}\log(r) + \sum_{\substack{p=0\\p\neq m}}^{\infty}\left[((p+n-m+1)c_{12} + c_{11})B_p - b_1L_p\right].r^{p+2n-m}$$

$$F_7(r) = (c_{13}\beta_1 + c_{13})r^{n+\beta_1-1}\ ,\ F_8(r) = (c_{13}\beta_2 + c_{13})r^{n+\beta_2-1}$$

$$F_9 = (c_{13}K_1(n-m+2) - b_2A)r^{2n-m} + ((n+2)c_{13}K_2 + c_{13}E_{m,n} - b_2B)r^{2n} +$$
$$((n+2)c_{13}E_{m,n} - b_2K_m)r^{2n}\log(r) + \sum_{\substack{p=0\\p\neq m}}^{\infty}\left[B_p(p+n-m+2)c_{13} - b_1L_p\right].r^{p+2n-m}$$

4. Particular Cases:

For m=1, n=1 we get corresponding results of S. A. Mollah [5]. For m=1, n=n we get corresponding results of De & Choudhury [2].

5. Numerical results and discussions:

We calculate our numerical results for the following range of parameters: $10 \le \mu \le 30$, $1.5 < b < 3.0$ and $a = 1$.

We consider the material to be made of magnesium, for which the elastic constants on the inner boundary $r = a = 1$ are given by [2]:

$c_{11} = 0.565\text{x}10^{12}$ dyne/cm^2,
$c_{12} = 0.232\text{x}10^{12}$ dyne/cm^2,
$c_{13} = 0.181\text{x}10^{12}$ dyne/cm^2,
$c_{33} = 0.587\text{x}10^{12}$ dyne/cm^2,
$c_{44} = 0.168\text{x}10^{12}$ dyne/cm^2.

The coefficients of linear thermal expansion of the said material on the inner boundary $r = a = 1$ are:

$\alpha_1 = 27.7\text{x}10^{-6}$ cms/c,
$\alpha_2 = 26.6\text{x}10^{-6}$ cms/c.

Further we choose arbitrarily: $T_i = 500^\circ\text{C}$ and $H_i = 1$

The Following table shows the variation of Radial stress and Hoop stress on the inner wall of the cylinder for m=2, n=2, $\mu = 10$ with variable thickness of the cylinder.

μ	r	σ_{rr}	$\sigma_{\theta\theta}$
10	1.00	0.066657×10^{13}	1.9677×10^{13}
	1.05	0.156399×10^{13}	2.0317×10^{13}
	1.10	0.246140×10^{13}	2.0955×10^{13}
	1.15	0.326000×10^{13}	2.1461×10^{13}
	1.20	0.404070×10^{13}	2.1967×10^{13}
	1.25	0.477120×10^{13}	2.23095×10^{13}
	1.30	0.548370×10^{13}	2.2652×10^{13}
	1.35	0.611740×10^{13}	2.2797×10^{13}
	1.40	0.669000×10^{13}	2.2942×10^{13}
	1.45	0.730920×10^{13}	2.2855×10^{13}
	1.50	0.786730×10^{13}	2.2768×10^{13}
	1.55	0.835060×10^{13}	2.24105×10^{13}
	1.60	0.868870×10^{13}	2.2053×10^{13}
	1.65	0.924070×10^{13}	2.1385×10^{13}
	1.70	0.964760×10^{13}	2.0717×10^{13}
	1.75	0.997530×10^{13}	1.96945×10^{13}
	1.80	1.001200×10^{13}	1.8672×10^{13}
	1.85	1.054700×10^{13}	1.725×10^{13}
	1.90	1.079100×10^{13}	1.5828×10^{13}
	1.95	1.094600×10^{13}	1.3958×10^{13}
	2.00	1.057900×10^{13}	1.2088×10^{13}

The Following table shows the variation of Radial stress and Hoop stress on the inner wall of the cylinder for m=2, n=2, $\mu = 20$ with variable thickness of the cylinder.

μ	r	σ_{rr}	$\sigma_{\theta\theta}$
	1.00	-01.0029×10^{18}	3.6968×10^{18}
	1.05	-2.33460×10^{18}	3.81815×10^{18}
	1.10	-03.6663×10^{18}	3.9395×10^{18}
	1.15	-4.84865×10^{18}	4.03695×10^{18}
	1.20	-06.0313×10^{18}	4.1344×10^{18}
	1.25	-7.08285×10^{18}	4.2025×10^{18}
	1.30	-08.1347×10^{18}	4.2706×10^{18}
	1.35	-9.06535×10^{18}	4.30345×10^{18}
20	1.40	-09.9960×10^{18}	4.3363×10^{18}
	1.45	-10.8095×10^{18}	4.3276×10^{18}
	1.50	-11.6230×10^{18}	4.3189×10^{18}
	1.55	-12.3200×10^{18}	4.26215×10^{18}
	1.60	-13.0170×10^{18}	4.2054×10^{18}
	1.65	-13.5935×10^{18}	4.0934×10^{18}
	1.70	-14.1700×10^{18}	3.9814×10^{18}
	1.75	-14.6205×10^{18}	3.8068×10^{18}
	1.80	-15.0710×10^{18}	3.6322×10^{18}
	1.85	-15.3885×10^{18}	3.38705×10^{18}
	1.90	-15.7060×10^{18}	3.1419×10^{18}
	1.95	-15.8805×10^{18}	2.8179×10^{18}
	2.00	-16.0550×10^{18}	2.4939×10^{18}

The following table shows the variation of Radial stress and Hoop stress on the inner wall of the cylinder for m=2, n=2, $\mu = 30$ with variable thickness of the cylinder.

μ	r	σ_{rr}	$\sigma_{\theta\theta}$
	1.00	-0.50916×10^{23}	2.9265×10^{23}
	1.05	-1.18493×10^{23}	3.02265×10^{23}
	1.10	-1.86070×10^{23}	3.1188×10^{23}
	1.15	-2.46075×10^{23}	3.19615×10^{23}
	1.20	-3.06080×10^{23}	3.2735×10^{23}
	1.25	-3.5944×10^{23}	3.3277×10^{23}
	1.30	-4.12800×10^{23}	3.3819×10^{23}
30	1.35	-4.60025×10^{23}	3.4083×10^{23}
	1.40	-5.07250×10^{23}	3.4347×10^{23}
	1.45	-5.4854×10^{23}	3.42845×10^{23}
	1.50	-5.89830×10^{23}	3.4222×10^{23}
	1.55	-6.2518×10^{23}	3.378×10^{23}
	1.60	-6.60530×10^{23}	3.3338×10^{23}
	1.65	-6.8978×10^{23}	3.24615×10^{23}
	1.70	-7.19030×10^{23}	3.1586×10^{23}
	1.75	-7.4189×10^{23}	3.0217×10^{23}
	1.80	-7.64750×10^{23}	2.8848×10^{23}
	1.85	-7.80835×10^{23}	2.6924×10^{23}
	1.90	-7.96920×10^{23}	2.5000×10^{23}
	1.95	-8.05755×10^{23}	1.84956×10^{23}
	2.00	-8.14590×10^{23}	1.9912×10^{23}

Following graphs show the variation of radial stress (σ_{rr}) on the inner wall of the cylinder with variable thickness of the cylinder.

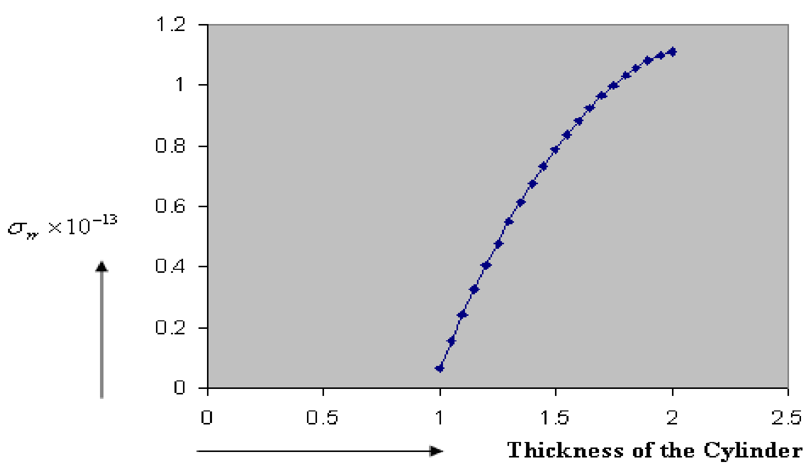

Fig1.

Fig1: Variation of the radial stress on the inner wall of the cylinder with the variable thickness of the cylinder when $\mu = 10$, m=2, n=2.

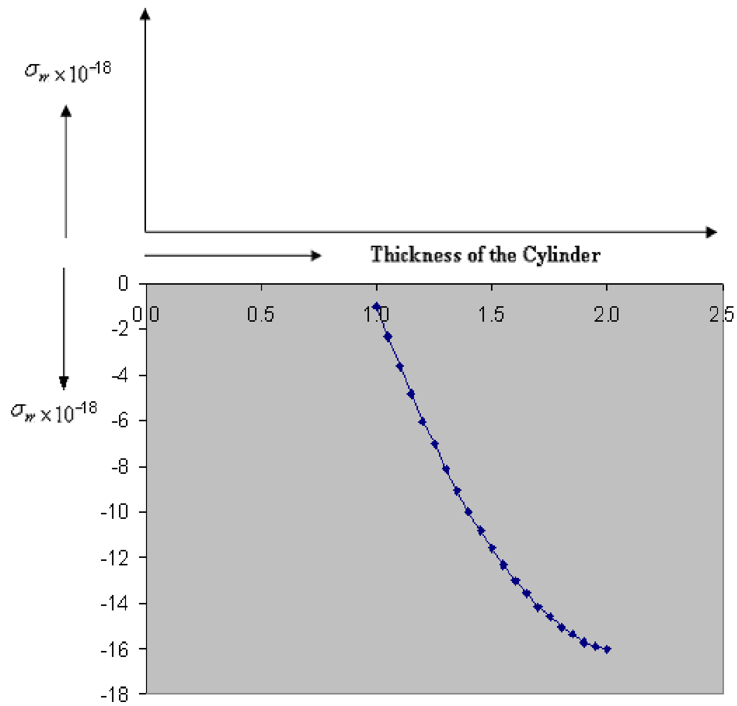

Fig2.

Fig2: Variation of the radial stress on the inner wall of the cylinder with the variable thickness of the cylinder when $\mu = 20$, m=2, n=2.

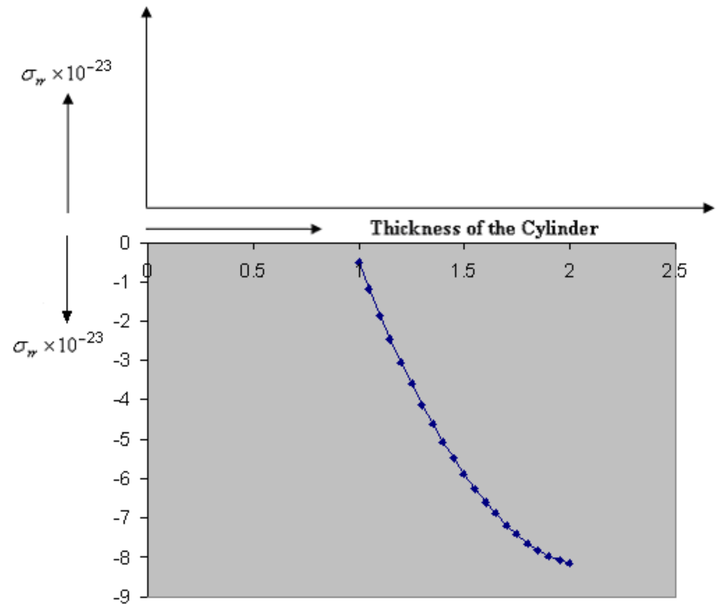

Fig3.

Fig3: Variation of the radial stress on the inner wall of the cylinder with the variable thickness of the cylinder when $\mu = 30$, m=2, n=2.

Following graphs show the variation of Hoop stress on the inner wall of the cylinder with variable thickness of the cylinder.

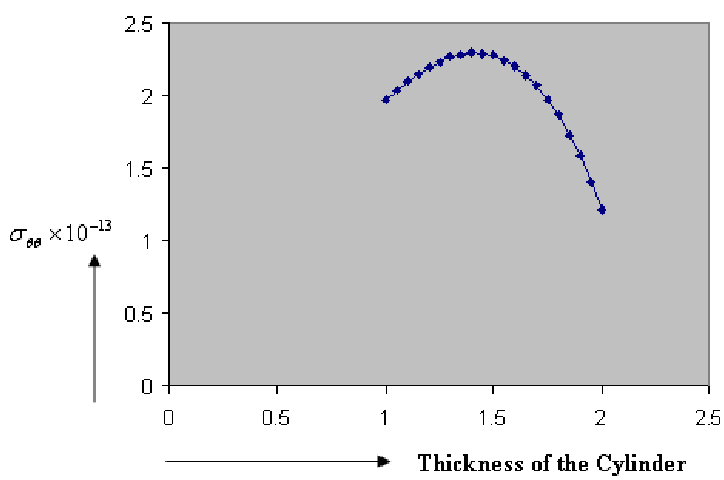

Fig4.

Fig4: Variation of the Hoop stress on the inner wall of the cylinder with the variable thickness of the cylinder when $\mu = 10$, m=2, n=2.

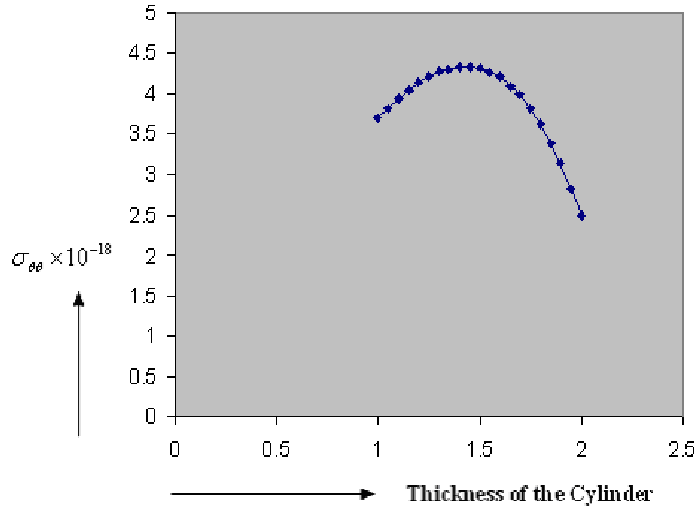

Fig5.

Fig5: Variation of the Hoop stress on the inner wall of the cylinder with the variable thickness of the cylinder when $\mu = 20$, m=2, n=2.

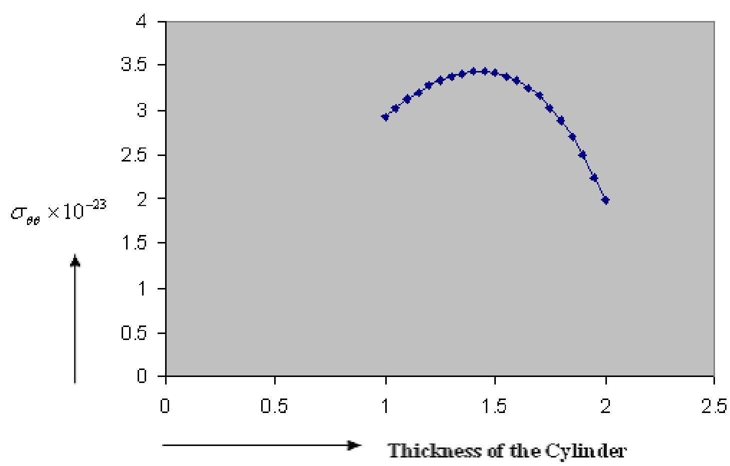

Fig6.

Fig6: Variation of the Hoop stress on the inner wall of the cylinder with the variable thickness of the cylinder when $\mu = 30$, m=2, n=2.

5. Conclusion:

In case of figure 1, for $\mu = 10$, the radial stress gradually increases with increasing thickness of the cylinder and in figure 2 and 3, for $\mu = 20,30$ the radial stress gradually decreases with increasing thickness .Here one thing we notice that for all values of μ the hoop stress initially increases and reaches to a maximum value and after some time it gradually decreases with increasing thickness. In figure 4, 5 and 6 for $\mu = 10$, 20 and 30 respectively, we see that the hoop stress gradually increases and reaches to a maximum value and after some time it gradually decreases with increasing thickness.

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