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Thermal Stresses of a Hollow Cylinder Due to Heat Generation: Steady State Problem

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Abstract-In this paper, an attempt has been made to study thermoelastic response of a hollow cylinder occupying the space $D: a \le r \le b,\ -h \le z \le h,$ ***due to heat generation with radiation type boundary conditions. Here we apply integral transform techniques to find the thermo elastic solution.***

Keywords: **Thermo elastic problem, hollow cylinder, Thermal Stresses, integral transform.**

I. INTRODUCTION

Khobragade et al. [2-18] have investigated temperature distribution, displacement function, and stresses of a thin as well as thick hollow cylinder and **Khobragade et al**. [13] have established displacement function , temperature distribution and stresses of a semi-infinite cylinder.

In the present paper, an attempt is made to study the theoretical solution for a thermoelastic problem to determine the temperature distribution, displacement and stress functions of a hollow cylinder with boundary conditions occupying the space

$$D = \{(x,y,z) \in R^3 : a \le (x^2+y^2)^{1/2} \le b,\ 0 \le z \le h\}$$

, where $r = (x^2+y^2)^{1/2}$. A transform defined by Zgrablich et al. [2] is used for investigation which is a generalization of Hankel's double radiation finite transform and used to treat the problem with radiation type boundaries conditions.

II. FORMULATION OF THE PROBLEM

Consider a hollow cylinder as shown in the figure 1. The material of the cylinder is isotropic, homogenous and all properties are assumed to be constant. We assume that the cylinder is of a small thickness and its boundary surfaces remain traction free. The initial temperature of the cylinder is the same as the temperature of the surrounding medium, which is kept constant.

The displacement function $\phi(r, z)$ satisfying the differential equation as Khobragade [2] is

$$\frac{\partial^2\phi}{\partial r^2} + \frac{1}{r}\frac{\partial\phi}{\partial r} + \frac{\partial^2\phi}{\partial z^2} = \left(\frac{1+\nu}{1-\nu}\right)a_t T \qquad (1)$$

with $\phi = 0$ at $r = a$ and $r = b$ (2)

where ν and a_t are Poisson ratio and linear coefficient of thermal expansion of the material of the cylinder respectively and $T(r, z)$ is the heating temperature of the cylinder satisfying the differential equation as Khobragade [2] is

$$\left[\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial T}{\partial r}\right) + \frac{\partial^2 T}{\partial z^2}\right] + \frac{g(r,z)}{k} = 0 \qquad (3)$$

where $\kappa = K/\rho c$ is the thermal diffusivity of the material of the cylinder, K is the conductivity of the medium, c is its specific heat and ρ is its calorific capacity (which is assumed to be constant) respectively, subject to the boundary conditions

$M_r(T, 1, \bar{\bar{k}}_1, a) = F_1(z)$, for all $0 \le z \le h$, (4)

$M_r(T, 1, \bar{\bar{k}}_2, b) = F_2(z)$ for all $0 \le z \le h$, (5)

$M_z(T, 0, 1, 0) = F_3(r)$ for all $a \le r \le b$, (6)

$M_z(T, 0, 1, \xi) = F_4(r)$ for all $a \le r \le b$, (7)

$M_z(T, 1, 0, h) = G(r)$ (Unknown) for all $a \le r \le b$ (8)

being:

$$M_{\vartheta}(f, \bar{k}, \bar{\bar{k}}, \$) = (\bar{k}\ f + \bar{\bar{k}}\ \hat{f})_{\vartheta = \$} \qquad (9)$$

Where the prime (^) denotes differentiation with respect to ϑ, radiation constants are $\bar{k}$ and $\bar{\bar{k}}$ on the curved surfaces of the plate respectively.

The radial and axial displacement U and W satisfy the uncoupled thermoelastic equation as Khobragade [2] are

$$\nabla^2 U - \frac{U}{r^2} + (1-2\nu)^{-1}\frac{\partial e}{\partial r} = 2\left(\frac{1+\nu}{1-2\nu}\right)a_t\frac{\partial T}{\partial r} \qquad (10)$$

$$\nabla^2 W + (1-2\nu)^{-1}\frac{\partial e}{\partial z} = 2\left(\frac{1+\nu}{1-2\nu}\right)a_t\frac{\partial T}{\partial z} \qquad (11)$$

Where

$$e = \frac{\partial U}{\partial r} + \frac{U}{r} + \frac{\partial W}{\partial r} \qquad (12)$$

$$U = \frac{\partial\phi}{\partial r}, \qquad (13)$$

$$W = \frac{\partial\phi}{\partial z} \qquad (14)$$

The stress functions are given by

$$\tau_{rz}(a, z) = 0,\ \tau_{rz}(b, z) = 0,\ \tau_{rz}(r, 0) = 0 \qquad (15)$$

$$\sigma_r(a, z) = p_i,\ \sigma_r(b, z) = -p_o,\ \sigma_z(r, 0) = 0 \qquad (16)$$

where p_i and p_o are the surface pressure assumed to be uniform over the boundaries of the cylinder. The stress functions are expressed in terms of the displacement components by the following relations as Khobragade [2] are

$$\sigma_z = (\lambda + 2G)\frac{\partial W}{\partial z} + \lambda\left(\frac{\partial U}{\partial r} + \frac{U}{r}\right) \tag{17}$$

$$\sigma_\theta = (\lambda + 2G)\frac{U}{r} + \lambda\left(\frac{\partial U}{\partial r} + \frac{\partial W}{\partial z}\right) \tag{18}$$

$$\tau_{rz} = G\left(\frac{\partial W}{\partial r} + \frac{\partial U}{\partial z}\right) \tag{19}$$

where $\lambda = 2G\nu/(1-2\nu)$ is the Lame's constant, G is the shear modulus and U, W are the displacement components.

Equations (1)-(19) constitute the mathematical formulation of the problem under consideration.

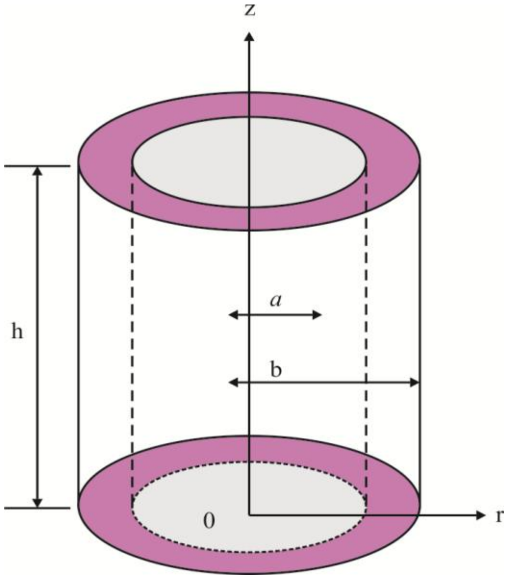

Fig 1: Geometry of the problem

III. SOLUTION OF THE OF THE PROBLEM

Applying finite March Zgrablich transform to (3), (6) & (7) & using (4) & (5), one obtains

$$\frac{d^2\overline{T}}{dz^2} - \mu_n^2\overline{T} = Q(z) \tag{20}$$

Where

$$Q(z) = \frac{a}{k_1} S_0(k_1, k_2, \mu_n a) F_1(z) - \frac{b}{k_2} S_0(k_1, k_2, \mu_n b) F_2(z) - \frac{\overline{g}(n,z)}{k}$$

$$\left[\frac{d\overline{T}}{dz}\right]_{z=0} = \overline{F}_3(n) \tag{21}$$

$$\left[\frac{d\overline{T}}{dz}\right]_{z=\xi} = \overline{F}_4(n) \tag{22}$$

Where $\overline{T}$ is the Marchi-Zgrablich transform of T & n is the Marchi-Zgrablich transform parameter equation (20) is a second order differential equation whose solution is given by

$$\overline{T}(n,z) = Ae^{\mu_n z} + Be^{-\mu_n z} + P.I \tag{23}$$

Using equation (21) & (22) in (23) we obtain the values of A & B.

Substituting these values in (23) & then inversion of finite Marchi-Zgrablich transform leads to

$$T(r,z) = \sum_{n=1}^{\infty} \frac{1}{C_n} \left\{ \frac{\left[\left[\overline{F}_4(n) - \left(\frac{d}{dz}(P.I) \right)_{z=\xi} \right] \cosh(\mu_n z) - \left[\overline{F}_3(n) - \left(\frac{d}{dz}(P.I) \right)_{z=0} \right] \cosh(\mu_n (z-\xi)) \right]}{\mu_n \sinh(\mu_n \xi)} \right\} \times S_0(k_1, k_2, \mu_n r) \tag{24}$$

Also,

$$G(r) = \sum_{n=1}^{\infty} \frac{1}{C_n} \left\{ \frac{\left[\left[\overline{F}_4(n) - \left(\frac{d}{dz}(P.I) \right)_{z=\xi} \right] \cosh(\mu_n h) - \left[\overline{F}_3(n) - \left(\frac{d}{dz}(P.I) \right)_{z=0} \right] \cosh(\mu_n (h-\xi)) \right]}{\mu_n \sinh(\mu_n \xi)} + [(P.I)] \right\} \times S_0(k_1, k_2, \mu_n r) \tag{25}$$

IV. THERMO ELASTIC DISPLACEMENT

Substituting value of T(r,z) from (24) in equation (1),we get

$$\phi(r,z,t) = \frac{r^2}{4} a_t \left(\frac{1+\upsilon}{1-\upsilon} \right) \sum_{n=1}^{\infty} \frac{1}{C_n} \left\{ \frac{\left[\left[\overline{F}_4(n) - \left(\frac{d}{dz}(P.I) \right)_{z=\xi} \right] \cosh(\mu_n z) - \left[\overline{F}_3(n) - \left(\frac{d}{dz}(P.I) \right)_{z=0} \right] \cosh(\mu_n (z-\xi)) \right]}{\mu_n \sinh(\mu_n \xi)} + P.I \right\} \times S_0(k_1, k_2, \mu_n r) \tag{4.1}$$

Using equation (4.1) in (2.13) and (2.14), one obtains the radial & axial displacement U & W as,

$$U=\left(\frac{1+\upsilon}{1-\upsilon}\right)\frac{a_t}{4}\sum_{n=1}^{\infty}\frac{1}{C_n}\left\{\frac{\left[\begin{array}{l}\left[\overline{F}_4(n)-\left(\frac{d}{dz}(P.I)\right)_{z=\xi}\right]\cosh(\mu_n z)\\-\left[\overline{F}_3(n)-\left(\frac{d}{dz}(P.I)\right)_{z=0}\right]\cosh(\mu_n(z-\xi))\end{array}\right]}{\mu_n\sinh(\mu_n\xi)}+P.I\right\}$$

$$\times\left[2rS_0(k_1,k_2,\mu_n r)+r^2\mu_n S_0'(k_1,k_2,\mu_n r)\right]\quad(26)$$

$$W=\frac{r^2}{4}a_t\left(\frac{1+\upsilon}{1-\upsilon}\right)\sum_{n=1}^{\infty}\frac{1}{C_n}\left\{\frac{\left[\begin{array}{l}\left[\overline{F}_4(n)-\left(\frac{d}{dz}(P.I)\right)_{z=\xi}\right]\cosh(\mu_n z)\\-\left[\overline{F}_3(n)-\left(\frac{d}{dz}(P.I)\right)_{z=0}\right]\cosh(\mu_n(z-\xi))\end{array}\right]}{\mu_n\sinh(\mu_n\xi)}+\frac{d}{dz}(P.I)\right\}$$

$$\times S_0(k_1,k_2,\mu_n r)\quad(27)$$

V. DETERMINATION OF STRESS FUNCTIONS

Using (4.2) & (4.3) in the equation (2.17) to (2.20) the stress function are obtained as

$$\sigma_r=(\lambda+2G)\left(\frac{1+\upsilon}{1-\upsilon}\right)\frac{a_t}{4}\sum_{n=1}^{\infty}\frac{1}{C_n}\left\{\frac{\left[\begin{array}{l}\left[\overline{F}_4(n)-\left(\frac{d}{dz}(P.I)\right)_{z=\xi}\right]\cosh(\mu_n z)\\-\left[\overline{F}_3(n)-\left(\frac{d}{dz}(P.I)\right)_{z=0}\right]\cosh(\mu_n(z-\xi))\end{array}\right]}{\mu_n\sinh(\mu_n\xi)}+P.I\right\}$$

$$\times\left[2S_0(k_1,k_2,\mu_n r)+4r\mu_n S_0'(k_1,k_2,\mu_n r)+r^2\mu_n^2 S_0''(k_1,k_2,\mu_n r)\right]$$

$$\left\{+\lambda\left(\frac{1+\upsilon}{1-\upsilon}\right)\frac{a_t}{4}\sum_{n=1}^{\infty}\frac{1}{C_n}\left\{\frac{\left[\begin{array}{l}\left[\overline{F}_4(n)-\left(\frac{d}{dz}(P.I)\right)_{z=\xi}\right]\cosh(\mu_n z)\\-\left[\overline{F}_3(n)-\left(\frac{d}{dz}(P.I)\right)_{z=0}\right]\cosh(\mu_n(z-\xi))\end{array}\right]}{\mu_n\sinh(\mu_n\xi)}+P.I\right\}\right\}$$

$$\times S_0(k_1,k_2,\mu_n r)\quad(28)$$

$$\sigma_z=(\lambda+2G)\frac{r^2}{4}a_t\left(\frac{1+\upsilon}{1-\upsilon}\right)\sum_{n=1}^{\infty}\frac{1}{C_n}\left\{\frac{\mu_n\left[\begin{array}{l}\left[\overline{F}_4(n)-\left(\frac{d}{dz}(P.I)\right)_{z=\xi}\right]\cosh(\mu_n z)\\-\left[\overline{F}_3(n)-\left(\frac{d}{dz}(P.I)\right)_{z=0}\right]\cosh(\mu_n(z-\xi))\end{array}\right]}{\mu_n\sinh(\mu_n\xi)}+\frac{d^2}{dz^2}(P.I)\right\}$$

$$\times S_0(k_1,k_2,\mu_n r)$$

$$\times\left[2S_0(k_1,k_2,\mu_n r)+r\mu_n S_0'(k_1,k_2,\mu_n r)\right]$$

$$+\frac{r^2}{4}a_t\left(\frac{1+\upsilon}{1-\upsilon}\right)\sum_{n=1}^{\infty}\frac{1}{C_n}\left\{\frac{\mu_n\left[\begin{array}{l}\left[\overline{F}_4(n)-\left(\frac{d}{dz}(P.I)\right)_{z=\xi}\right]\cosh(\mu_n z)\\-\left[\overline{F}_3(n)-\left(\frac{d}{dz}(P.I)\right)_{z=0}\right]\cosh(\mu_n(z-\xi))\end{array}\right]}{\mu_n\sinh(\mu_n\xi)}+\frac{d^2}{dz^2}(P.I)\right\}$$

$$\times S_0(k_1,k_2,\mu_n r)$$

$$+\lambda\left\{\begin{array}{l}\left(\frac{1+\upsilon}{1-\upsilon}\right)\frac{a_t}{4}\sum_{n=1}^{\infty}\frac{1}{C_n}\left\{\frac{\left[\begin{array}{l}\left[\overline{F}_4(n)-\left(\frac{d}{dz}(P.I)\right)_{z=\xi}\right]\cosh(\mu_n z)\\-\left[\overline{F}_3(n)-\left(\frac{d}{dz}(P.I)\right)_{z=0}\right]\cosh(\mu_n(z-\xi))\end{array}\right]}{\mu_n\sinh(\mu_n\xi)}+P.I\right\}\\ \times\left[2S_0(k_1,k_2,\mu_n r)+4r\mu_n S_0'(k_1,k_2,\mu_n r)+r^2\mu_n^2 S_0''(k_1,k_2,\mu_n r)\right]\\ +\left(\frac{1+\upsilon}{1-\upsilon}\right)\frac{a_t}{4}\sum_{n=1}^{\infty}\frac{1}{C_n}\left\{\frac{\mu_n\left[\begin{array}{l}\left[\overline{F}_4(n)-\left(\frac{d}{dz}(P.I)\right)_{z=\xi}\right]\cosh(\mu_n z)\\-\left[\overline{F}_3(n)-\left(\frac{d}{dz}(P.I)\right)_{z=0}\right]\cosh(\mu_n(z-\xi))\end{array}\right]}{\mu_n\sinh(\mu_n\xi)}+(P.I)\right\}\\ \times\left[2S_0(k_1,k_2,\mu_n r)+r\mu_n S_0'(k_1,k_2,\mu_n r)\right]\end{array}\right\}$$

$$(29)$$

$$\sigma_\theta=(\lambda+2G)\left(\frac{1+\upsilon}{1-\upsilon}\right)\frac{a_t}{4}\sum_{n=1}^{\infty}\frac{1}{C_n}\left\{\frac{\mu_n\left[\begin{array}{l}\left[\overline{F}_4(n)-\left(\frac{d}{dz}(P.I)\right)_{z=\xi}\right]\cosh(\mu_n z)\\-\left[\overline{F}_3(n)-\left(\frac{d}{dz}(P.I)\right)_{z=0}\right]\cosh(\mu_n(z-\xi))\end{array}\right]}{\mu_n\sinh(\mu_n\xi)}+(P.I)\right\}$$

$$\times\left[2S_0(k_1,k_2,\mu_n r)+r\mu_n S_0'(k_1,k_2,\mu_n r)\right]$$

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$$+\lambda\left\{\begin{array}{l}
\left(\frac{1+\upsilon}{1-\upsilon}\right)\frac{a_t}{4}\sum_{n=1}^{\infty}\frac{1}{C_n}\left\{\frac{\begin{bmatrix}\left[\bar{F}_4(n)-\left(\frac{d}{dz}(P.I)\right)_{z=\xi}\right]\cosh(\mu_n z)\\ -\left[\bar{F}_3(n)-\left(\frac{d}{dz}(P.I)\right)_{z=0}\right]\cosh\left(\mu_n(z-\xi)\right)\end{bmatrix}}{\mu_n\sinh(\mu_n\xi)}+P.I\right\}\\
\times\left[2S_0(k_1,k_2,\mu_n r)+4r\mu_n S_0'(k_1,k_2,\mu_n r)+r^2\mu_n^2 S_0''(k_1,k_2,\mu_n r)\right]\\
+\frac{r^2}{4}a_t\left(\frac{1+\upsilon}{1-\upsilon}\right)\sum_{n=1}^{\infty}\frac{1}{C_n}\left\{\frac{\mu_n\begin{bmatrix}\left[\bar{F}_4(n)-\left(\frac{d}{dz}(P.I)\right)_{z=\xi}\right]\cosh(\mu_n z)\\ -\left[\bar{F}_3(n)-\left(\frac{d}{dz}(P.I)\right)_{z=0}\right]\cosh\left(\mu_n(z-\xi)\right)\end{bmatrix}}{\mu_n\sinh(\mu_n\xi)}+\frac{d^2}{dz^2}(P.I)\right\}\\
\times S_0(k_1,k_2,\mu_n r)
\end{array}\right\}$$

(30)

$$\tau_{rz}=G\left\{\begin{array}{l}
\frac{a_t}{4}\left(\frac{1+\upsilon}{1-\upsilon}\right)\sum_{n=1}^{\infty}\frac{1}{C_n}\left\{\frac{\begin{bmatrix}\left[\bar{F}_4(n)-\left(\frac{d}{dz}(P.I)\right)_{z=\xi}\right]\cosh(\mu_n z)\\ -\left[\bar{F}_3(n)-\left(\frac{d}{dz}(P.I)\right)_{z=0}\right]\cosh\left(\mu_n(z-\xi)\right)\end{bmatrix}}{\mu_n\sinh(\mu_n\xi)}+\frac{d}{dz}P.I\right\}\\
\times\left[2rS_0(k_1,k_2,\mu_n r)+r^2\mu_n S_0'(k_1,k_2,\mu_n r)\right]\\
+\left(\frac{1+\upsilon}{1-\upsilon}\right)\frac{a_t}{4}\sum_{n=1}^{\infty}\frac{1}{C_n}\left\{\frac{\begin{bmatrix}\left[\bar{F}_4(n)-\left(\frac{d}{dz}(P.I)\right)_{z=\xi}\right]\cosh(\mu_n z)\\ -\left[\bar{F}_3(n)-\left(\frac{d}{dz}(P.I)\right)_{z=0}\right]\cosh\left(\mu_n(z-\xi)\right)\end{bmatrix}}{\mu_n\sinh(\mu_n\xi)}+\frac{d}{dz}(P.I)\right\}\\
\times\left[2rS_0(k_1,k_2,\mu_n r)+r^2\mu_n S_0'(k_1,k_2,\mu_n r)\right]
\end{array}\right\}$$

(31)

VI. SPECIAL CASE

Set $f_3 = 0,\ f_4 = \delta(r - r_0)$ (32)

Applying finite Marchi Zgrablich transform defined in [2] to the equation (31) one obtains

$\bar{f}_3 = 0$ & $\bar{f}_4 = r_0\, S_0(k_1, k_2, \mu_n r_0)$ (33)

Substituting the value of (32) in the equation (21) to obtain

$$T(r,z)=\sum_{n=1}^{\infty}\frac{1}{c_n}\frac{\left[r_0S_0(k_1,k_2,\mu_m r_0)-\left(\frac{d}{dz}P.I\right)_{z=\xi}\right]\cosh(\mu_n z)+\left(\frac{d}{dz}P.I\right)_{z=0}\cosh\left(\mu_n(z-\xi)\right)}{\mu_n\sinh(\mu_n\xi)}\times S_0(k_1,k_2,\mu_n r)$$

(34)

VII. NUMERICAL RESULTS

Take $k_1 = 0.25, k_2 = 0.25, r_0 = 1$

$$T(r,z)=\sum_{n=1}^{\infty}\frac{1}{c_n}\frac{\left[S_0(0.25,0.25,\mu_n)-\left(\frac{d}{dz}P.I\right)_{z=\xi}\right]\cosh(\mu_n z)+\left(\frac{d}{dz}P.I\right)_{z=0}\cosh\left(\mu_n(z-\xi)\right)}{\mu_n\sinh(\mu_n\xi)}\times S_0(0.25,0.25,\mu_n r)$$

(35)

VIII. CONCLUSION

In this paper, we modified the conceptual idea proposed by **Khobragade et al** [2] for hollow cylinder and the temperature distributions, displacement and stress functions at the edge $z = h$ occupying the region of the cylinder $a \le r \le b,\ \ 0 \le z \le h$ have been obtained with the known boundary conditions. We develop the analysis for the temperature field by introducing the transformation defined by Zgrablich et al with boundary conditions of radiation type. Since the thickness of cylinder is very small, the series solution given here will be definitely convergent. Assigning suitable values to the parameters and functions in the series expressions can derive any particular case. The temperature, displacement and thermal stresses that are obtained can be applied to the design of useful structures or machines in engineering applications.

REFERENCES

[1] Noda, N; Hetnarski, R.B; Tanigawa, Y: Thermal Stresses, second edition Taylor & Francis, New York (2003), 260.

[2] Gahane, T.T, Varghese, V. and Khobragade, N. W (2009): “Transient Thermoelastic Problem of a cylinder with heat sources”, Int. J Latest Trend Math, Vol. 2 No. 1, pp. 25-36, 2012.

[3] Raut, G.N., Varghese, V. and Khobragade, N. W. (2009): “On the plane strain and plane stress solutions of uniformly heated functionally graded solid cylinder or disc problems”, Advances in Math. Sci. and Appl., vol. 19, No.1, 403-413.

[4] Kamdi, D. B, Khobragade, N. W, and Durge, M. H (2009): “Transient Thermoelastic Problem for a Circular Solid

Cylinder with Radiation", Int. Journal of Pure and Applied Maths, vol. 54, No. 3, 387-406, Academic Publication.

[5] Kulkarni, Ashwini A and Khobragade, N. W (2012): "Thermal stresses of a finite length hollow cylinder", Canadian Journal on Science and Engg. Mathematics Research, Vol. 3 No. 2, pp. 52-55.

[6] Warbhe, M. S and Khobragade, N.W (2012): "Numerical Study Of Transient Thermoelastic Problem Of A Finite Length Hollow Cylinder", Int. Journal of Latest Trends in Maths, Vol. 2, No. 1, pp. 4-9.

[7] Lamba, N.K; and Khobragade, N.W (2011): "Analysis of Coupled Thermal Stresses in a Axisymmetric Hollow Cylinder", Int. Journal of Latest Trends in Maths, Vol. 1, No. 2.

[8] Lamba, N.K, Walde, R. T and Khobragade, N.W (2012): "Stress functions in a hollow cylinder under heating and cooling processes", Journal of Statistics and Mathematics. Vol. 3, Issue 3, pp. 118-124, BIO INFO Publication

[9] Gahane, T. T and Khobragade, N.W (2012): "Transient Thermoelastic Problem Of A Semi-infinite Cylinder With Heat Sources", Journal of Statistics and Mathematics, Vol. 3, Issue 2, pp. 87-93, BIO INFO Publication.

[10] Hiranwar Payal C and Khobragade, N.W (2012): "Thermoelastic Problem Of A Cylinder With Internal Heat Sources", Journal of Statistics and Mathematics, Vol. 3, Issue 2, pp. 87-93, BIO INFO Publication.

[11] Dange, W. K; Khobragade, N.W, and Durge, M. H (2012): "Thermal Stresses of a finite length hollow cylinder due to heat generation", Int. J. of Pure and Appl. Maths, (accepted),

[12] N. W. Khobragade, Lalsingh Khalsa and Mrs Ashwini Kulkarni: Thermal Deflection of a Finite Length Hollow Cylinder due to Heat Generation, Int. J. of Engg. And Information Technology, vol. 3, Issue 1, pp. 372-375, (2013)

[13] Anjali C. Pathak, Payal Hiranwar, Lalsingh Khalsa and N. W. Khobragade (2013): Thermoelastic Problem Of A Semi Infinite Cylinder With Internal Heat Sources, Int. J. of Engg. And Information Technology, vol. 3, Issue 1,

[14] R.T. Walde , Anjali C. Pathak and N.W. Khobragade (2013): Thermal Stresses of a Solid Cylinder With Internal Heat Source, Int. J. of Engg. And Information Technology, vol. 3, Issue 1, pp. 407-410.

[15] Jadhav, C.M; and Khobragade, N.W (2013): "An Inverse Thermoelastic Problem of finite length thick hollow cylinder with internal heat sources", Advances in Applied Science Research, 4(3); 302-314

[16] Khobragade, N.W (2013): Thermal stresses of a hollow cylinder with radiation type conditions, Int. J. of Engg. And Information Technology, vol. 3, Issue 5, pp.25-32.

[17] Khobragade, N.W (2013): Thermoelastic analysis of a solid circular cylinder, Int. J. of Engg. And Information Technology, vol. 3, Issue 5, pp. 155-162.

[18] Khobragade, N.W (2013): Thermoelastic analysis of a thick hollow cylinder with radiation conditions, Int. J. of Engg. And Information Technology, vol. 3, Issue 4, pp.380-387.

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