ISSN 2395-1621

Contact stress analysis of kiln tyre and thrust roller by using normal loading

[#1]Prasad Ingawale, [#2]Kiran Narkar

P.G. Student, Dept. of Mechanical Engg., D.Y. Patil College of Engineering, Pune, Maharashtra, India[1]

Associate Professor, Dept. of Mechanical Engg., D.Y. Patil College of Engineering, Pune, Maharashtra, India [2]

ABSTRACT

This paper presents an analysis of the contact stress distribution between the outer surface of the riding tyre of rotary cement kiln and thruster roller during working cycle using both the theory and finite element simulation. In the theoretical analysis, the total stress is obtained by a contact stresses. Contact stress between kiln tyre and supporting thruster roller is obtained using Hertz contact theory.The existing analytical expression for pure rolling contact pressure in uniform cross section cylinder is modified to determine the contact area, contact pressure and stress distribution in conical kiln tyre and thruster roller under normal loading. The Hertzian contact pressure are determined for the modified pure rolling contact pressure distribution.

In addition, a more realistic kiln tyre model subjected to all loads simultaneously is also simulated.The theoretical results are compared with finite element analysis using ABACUS, for different vertex angles, materials and loads.

The results of theoretical model are found to be consistent with the finite element simulation in predicting the contact pressure, pressure distribution and stresses in roller. These results showed slight disagreement with theory in the contact region, mainly due to sliding contact between the thruster roller and the kiln tyre, but overall agreement was good.

Keywords—* *Cement Kiln, Tyre, Thruster Roller, Contact stresses, FEA etc.

ARTICLE INFO

Article History

Received :28th Septmber 2015

Received in revised form :

6th October 2015

Accepted : 8thOctober , 2015

Published online :

12th October 2015

I. INTRODUCTION

Rotary kiln is widely used in processing industries, such as cement, ore processing and chemical. The kiln is a cylindrical shell slightly inclined to the horizontal position and supported by tyres. A Girth gear and pinion assembly rotates the entire system. Material enters the kiln at the upper end and moves to words the lower end. With continuous mixing and a supply of hot air the desired chemical reaction is completed at the lower end and thus the processing is continuous. The kiln shell has a fire brick lining to protect the outer steel shell from the high temperatures existing inside. The tyre is a cylindrical ring supporting to the kiln shell. Tyre is cylindrical cast or forged single ring. Following picture gives overview of kiln tyre, shell, rollers and assembly.

Figure1.Overview kiln Assembly

Thrust roller is designed for accommodation of rotary cement kiln axial loads, control the axial motion and counteract the slope of kiln and ensure uniform use of the contact surface between kiln tyre and supporting roller.The analysis of contact stresses between simple geometries like cylindrical parts or spherical parts have attracted the attentions of many researchers. There are lots of works on these simple geometries. Heinrich Hertz[1] for the first time analyzed the contact stresses by determining the loading distribution over the contact area and provided the mathematical models for the stress field using a potential function for the case of spherical contact.Hertz only considered spherical contact for his analysis. And for a long time there was no remarkable research on contact problems. Every contact problems were solved on Hertz spherical contact theory. Al Zain [1] analyzed the contact problem between two conical rollers under the normal loading.

There are a limited number of studies in literature that examine stress state of rotary kiln rings in more details. Maziarz and Tasak studied fatigue failure of the rings and gave simplified equations for bending stresses caused by continuous load; detailed analysis of contact and thermal stresses was omitted. Alma Zigaand and AleksandarKarac [2] studied the contact analysis between kiln tyre and support roller. But no one did research on Kiln tyre and thrust roller for normal loading and also finite element verification.

This paper focuses on detailed analytical analysis of the kiln ring tyre stresses caused by continuous loads, contact between the ring and the thrust roller and by finite simulation of the same problem. It is a 70 m long steel tube with inner diameter of 6.6 m and slope of 3.5°, and rotation speed of 2 rpm. The mass of the kiln, including refractory line and feed, is around 1000 t and is supported by three ring-roller stations, spaced along the length of the kiln. The main dimensions and properties of the kiln necessary for subsequent analysis are given in Tab.

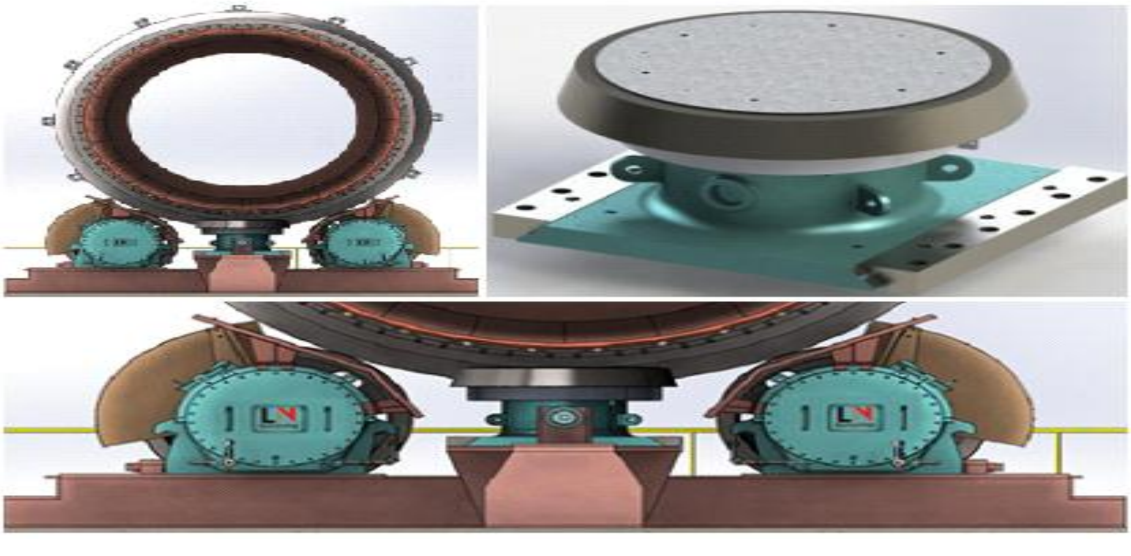

Figure 2 General arrangement of roller station
Table No. 1 Rotary Kiln data

Thrust Angle (deg.)	**9.5**	**10**	**10.69**	**11.5**	**12**
Kiln Tyre diameter (in mm)	**6625**	**6625**	**6625**	**6625**	**6625**
Thrust Roller diameter (in mm)	**1100**	**1180**	**1250**	**1355**	**1410**

II. ANALYTICAL SOLUTION

When two geometrically different and materially identical conical rollers come into contact with each other under the application of a uniform compressive normal loading in rolling, the contact patch appears in the form of trapezoid, in contrast with two cylinders where the contact area is a rectangle.

2.1 Radius of Curvature

The radius of curvature of a conical roller is equal tothe radius of curvature of an ellipse formed by a cut plane normal to the external surface of the conical roller. This radius of curvature varies as the cut plane moves along the contact length. Figure 1 shows two ellipses in a side view formed by sectioning conical rollers by the cut plane at t.The radius of curvature of the osculating rollers for the section at t is

$$R_1 = R_2 = R = \frac{B^2}{A} \ldots o \le t \le l \quad (1)$$

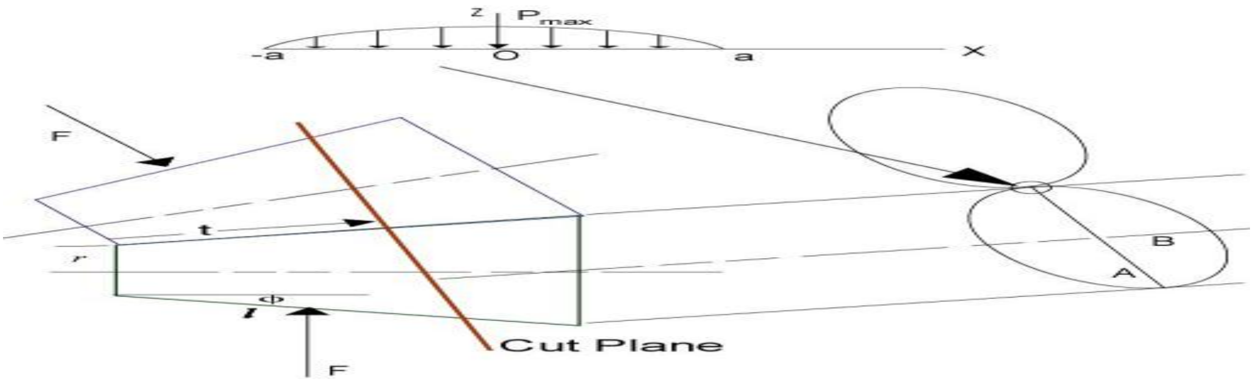

Figure 3. Two rollers in contact

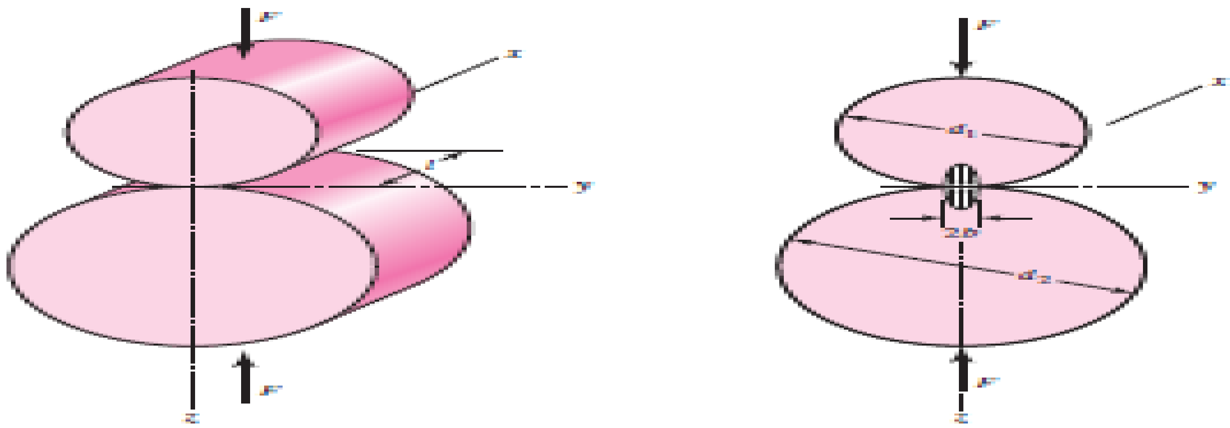

Figure 4. Contact stress distribution

Equation (1) is a parametric form of radius R of curvature, where all values of R along the contact length can be determined as t increases from 0 to *l*. A and B are the lengths of the major and minor axis respectively ofthe ellipses of osculating rollers 1(Kiln tyre) and 2(Thrust roller) at t, when viewed perpendicular to the section, as shown in figure 3. The lengths of the major and minor axes, which are also function of t, are determined by visualizing the cone in a three dimensional space The conical roller geometric constant b that depends only on the radii of curvature of two cones, at t is,

$$b = \frac{1}{2}\left\{\frac{1}{R1} + \frac{1}{R2}\right\} \quad \ldots\ldots\ldots\ldots\ldots..0<t<l(2)$$

It may be noted that like b, has a unique value for each value of t as long as long radius of curvature is not infinite or undefined.

Consider tyre outer diameter as d_2,thrust roller outer diameter as d_1, common width as l, half width of contact area is b.Thrust Force F = 450KN ,

Modulus of elasticity of kiln tyre and thrust roller is $E_2 = E_1 = 210000 N/mm^2$ and Poisson's ratio is $\nu_2 = \nu_1 = 0.3$ respectively.
Half contact width (a) is given by,

$$a = \sqrt{\frac{2*(m1+m2)*F}{\pi b l}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Maximum pressure P_{max} is,

$$P_{max} = \frac{2F}{\pi b l} \quad \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

So the maximum pressure calculated between kiln tyre (Roller1) and Thrust roller (Roller2) is 373 N/mm^2.

III. NUMERICAL SOLUTION

Numerical analysis is carried out using ABAQUS software [12]. In all simulations the kiln tyre and thrust rollers (where applied) are modelled in 2Das shown in figure 5 , with only a half of the model due to symmetry and plain strain condition is applied. Simulations are considered steady-state, i.e. inertia effects are neglected due to slow rotation of the kiln. Material properties for both parts are those of steel. Firstly, the kiln tyre is subjected to individual loads as employed in the analytical section, and results are compared with analytical solutions. Then, a more realistic model, with all loading conditions acting simultaneously, is simulated and analysed.

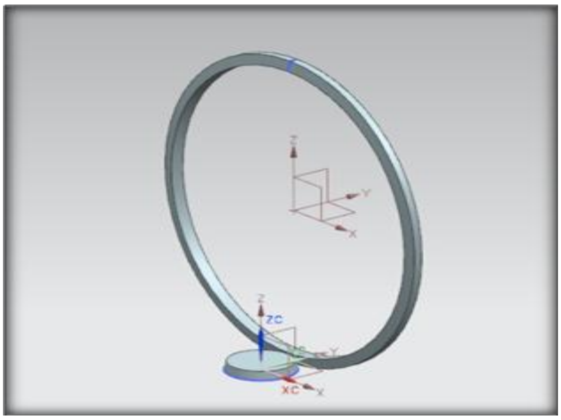

Figure 5. CAD 2D Model

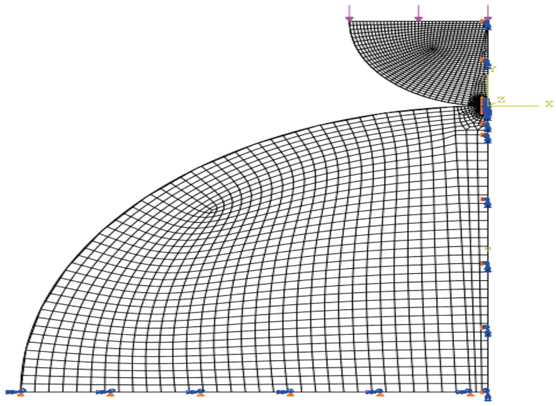

Figure 6. Contact between tyre and roller-simplified analysis

Contact stresses are obtained numerically using the model .Here, the kiln tyre ring and thrust roller are modelled as full cylinders to accommodate assumptions used in the analytical solution. Only a quarter of each part is modelled and the force *F* is applied to the roller (upper cylinder) as shown in Fig. 7

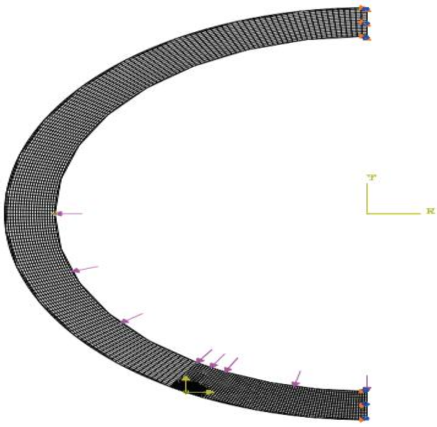

Figure 7. The ring model subjected to continuous load

The mesh consists of 4141 CPE4R elements for the ring and 4909 CPE4R elements for the roller, with refined mesh in the region of contact to obtain more accurate results. Outside boundaries are modelled as stress-free, with bottom and right boundaries as symmetry planes. Contact between the roller and the ring is modelled using frictionless formulation. The type of interaction between kiln tyre ring and thrust rollers is surface-to-surface with small slidingformulation and surface-to-surface discretisation method. As a result of this simulation, maximum (compressive) contact stress of 396 MPa is obtained in the middle of contact area, the same as analytically.

IV. CONCLUSION

Circumferential stresses of the kiln tyre caused by distributed loads, contact with supporting thrust rollers are analysed analytically and numerically. A good overall agreement between two approaches is obtained. However, numerical analysis of a more realistic kiln-tyre system revealed smaller compressive stresses in the contact region compared to the analytical predictions. The major contribution to the total stress is that of temperature and high compressive stresses, causing almost constant stress in the outer surface of the kiln tyre. Stress magnitudes are well below yield stress of the ring material. As thrust roller vertex angle increases the maximum pressure occur at contact region also decreases. The analytical and numerical results shows a small 8% variation in result but overall agreement is good.

REFRENCES

[1]A. Rayhan, M. WasimAkram, Md. Ali And S. C. Chowdhury ,Contact Stresses In Conical Rollers Under Normal And Tangential Loadings, *International Conference on Mechanical Engineering* 2009 (ICME2009) 26- 28 December 2009.

[2]Ziga A. , Carac AAnalytical and numerical stress analysis of the rotary kiln ring,*Technical Gazette* 20 941-946, 6(2013)

[3]Smith, J. O., and Liu, C. K., , ‘‘Stresses Due to Tangential and Normal Loads on an Elastic Solid with Application to Some Contact Stress Problems,’’ *ASME J. Appl. Mech*.20, pp. 157–166,1953.

[4]Wei Siang Sum, Edward J. Williams, Sean B. Leen. Finite element, critical-plane, fatigue life prediction of simpleand complex contact configurations. int. J. Fatigue,27(4) ,403-416,2005.

[5]VahidMonfared, Contact Stress Analysis in Rolling Bodies by Finite Element Method (FEM) Statically by *Journal of Mechanical Engineering and Automation* 2012, 2(2): 12-16.

[6]Ligia Cristina, Contact stresses between two cylindrical bodies with parallel axes: analysis by FEM, *Scientific Bulletin of the PetruMaior University of TîrguMureş* Vol. 10 (XXVII) no. 2, 2013

[7]Norton, R.L. Machine Design an integrated approach, 3rd edition, 2006 *(McGraw Hill,NewYark)*

[8]Timoshenko, S.P. and Goodier, J.N Theory of Elasticity , 3rd edition,1970 *(McGraw Hill,NewYark)*

[9]Shigley, J.E, Mischke, C.R and Budynas R.G. Mechanical engineering Design, 7thedition, 2004. *(McGrawHill,NewYark)*

