# Contact Stress Analysis of a Roller Conveyor

**Prayag. R. Shirolkar[1], Mr. Uday. B. Khadabadi [2], Mr. Vikas Adavale[3]**

*[1] M.Tech Student (Design Engineering), KLE. Dr. M.S.Sheshgiri College of Engineering & Technology, Belagavi, Karnataka, India*
*[2] Professor, Department of Mechanical Engineering, KLE. Dr. M.S.Sheshgiri College of Engineering & Technology, Belagavi, Karnataka, India*
*[3] Asst. Manager, Design-MHD, TAL Manufacturing Solutions Ltd, Pune, Maharashtra, India*

---------------------------------------------------------------------***---------------------------------------------------------------------

**Abstract –** ***In general, Roller Conveyors are designed with a set of elements to reduce cost, ease of assembly and manufacturability etc. In context to this, one also needs to address stress issues at the contact regions between any two elements; stress is induced when a load is applied to two elastic solids in contact. If not considered and addressed adequately, these stresses can cause serious flaws within the mechanical design and the end product may fail to qualify. The application of Hertizian contact stress equations can estimate maximum stress produced and ways to ease the stresses can be sought. In many cases, the resultant stresses are not of design significance, but in some cases failure can occur. The roller bearing assembly and spur gear pair assembly is an example where the assembly undergoes fatigue failure due to contact stresses. In this study, Roller conveyor conveying huge loads over varying lengths is considered. The pallet along with the load rolls over the rollers making a line contact in between. High stresses are generated in this case as the total load acts through this line of contact. A contact patch is generated at this line of contact. With CATIA, the parametric modeling at the interface of the roller and pallet is carried out. In the development phase, the contact stress analysis is carried out. The finite element analysis software ANSYS Workbench was used for this purpose. Results such as maximum contact pressure, maximum shear stress, and maximum principal stress are determined. A true assessment of the contact region is made so as to predict the behavior at extreme conditions. Finally, conclusions are drawn based on the theoretical and analytical results.***

***Key Words:*** *Contact stress analysis, Roller conveyor, Hertizian contact stresses, Theoretical calculations, FEA analysis using ANSYS Workbench, maximum contact pressure, maximum shear stress.*

## 1. Introduction

When two solid surfaces are loaded together there will always be some distortion of each of them. Deformations may be purely elastic or may involve some additional plastic, and so permanent, changes in shape. Stresses formed by the contact can cause extremely high surface stresses. These stresses can then be analyzed in context of the application. In many cases, the resultant stresses are not of design significance, but in some cases failure can occur. The study of deformation of solids under contact is called contact mechanics. Classical contact mechanics comprises of mechanics of material and continuum mechanics and assumes the deforming material to be isotropic and homogeneous; in principle, its results can be applied both to global contacts and to those between interacting asperities. Central aspects in contact mechanics are the adhesion and pressures acting perpendicular to the contacting surfaces (the normal direction) and the frictional stresses acting tangentially between the surfaces. Thus contact mechanics is divided into **Frictional contact mechanics** which deals with the study of deformation of bodies in the presence of frictional effects, and **Frictionless contact mechanics** which deals with the study of deformation of bodies in the absence of frictional effects. When any two curved bodies of different radii of curvature are brought in contact they will initially touch either at appoint or along a line. With the application of the smallest load, elastic deformation enlarges these into contact areas across which the loads are distributed as pressures. The first analysis of this situation was presented by Heinrich Hertz in1881. Hertz stress refers to the stress and deformation generated on bodies in contact under applied load. Any time there is a radius in contact with another radius or flat, contact stresses will occur.

The scope of the present study includes the contact stress analysis at the interface of the roller and pallet and hence comparing the analytical results with the theoretical calculated values.

### 1.1 Assumptions

The following assumptions and idealizations have been made for the analysis of the current problem.

 

1. It has been considered that both the roller and pallet are parallel to each other and single line contact takes place between them. The representation of the same is made in Fig -1.
2. Instead of using the model of complete roller and pallet as shown in Fig-1, the model is prepared considering the region where the actual contact occurs as shown in Fig -2.
3. Both the roller and pallet are made of homogeneous isotropic materials and are made of steel.
4. Both the roller and pallet namely the one in contact and the one considered as target are considered to be deformable bodies and are considered to behave in linear elastic manner.
5. It is also assumed that both surfaces that are in contact have smooth surfaces and shows no frictional behaviour when in contact.
6. Static conditions are considered for the contact analysis i.e. both roller and the pallet are at rest.

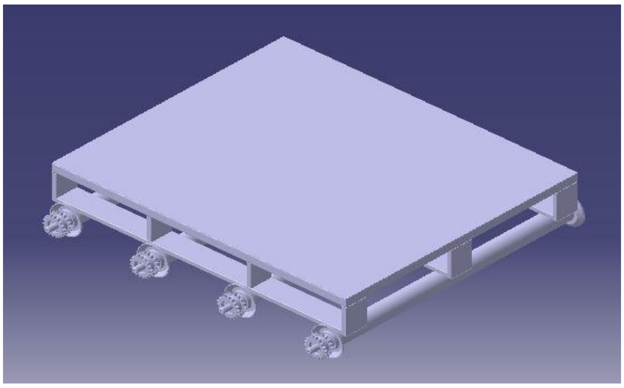

**Fig -1:** Complete model of pallet in contact with roller

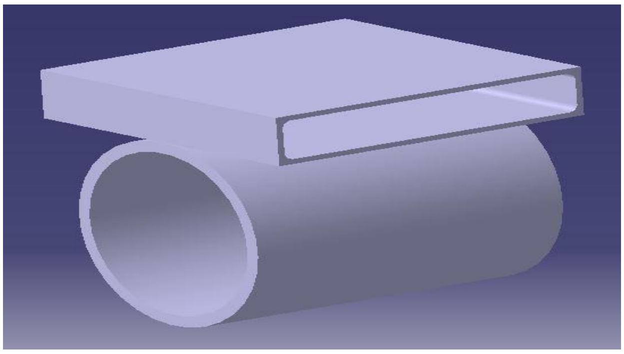

**Fig -2:** Model prepared for Contact stress analysis

## 1.2 Theoretical calculations

In the Roller conveyor system the pallet is making a line contact with the rollers. The resulting pressure causes the line of contact to become a rectangular zone of half width ‘b’. The half width b is given by

$$b = K_b\sqrt{F}$$

Where,

$$K_b = \left[\frac{2}{\pi l} \times \frac{\frac{(1-v_1^2)}{E_1} + \frac{(1-v_2^2)}{E_2}}{\frac{1}{d_1} + \frac{1}{d_2}}\right]^{1/2}$$

F = Applied force = 450 N

$v_1, v_2$ = Poisson’s ratio for roller and pallet = 0.3

$E_1, E_2$ = Young’s modulus for roller and pallet = 200 GPa

$d_1, d_2$ = Diameters of roller and pallet = 76 mm

l = Length of roller and pallet ($l_1 = l_2$ assumed) = 100 mm

In the present case, the pallet is a plane ($d_2 = \infty$ )

Solving, we get

$$b = 0.0445 \text{ mm}$$

The maximum contact pressure between the pallet and roller acts along a longitudinal line at the centre of the rectangular contact area, and is computed as:

$$p_{max} = \frac{2F}{\pi b l}$$

$$p_{max} = \mathbf{64.36\ MPa}$$

The state of stress is computed based on the following mechanics:

1. One plane of symmetry in loading and geometry dictates that: $\sigma_x \neq \sigma_y$;
2. The dominant stress occurs on the axis of loading: $\sigma_{max} = \sigma_z$;
3. The principal stresses are equal to $\sigma_x$, $\sigma_y$ and $\sigma_z$ with $\sigma_3 = \sigma_z$;
4. Compressive loading leads to $\sigma_x$, $\sigma_y$ and $\sigma_z$ being compressive stresses.

## 1.3 Calculation of Principal stresses and Maximum shear stress

$$\sigma_1 = \sigma_x = -2vp_{max}\left[\sqrt{1+\propto_b^2} - |\propto_b|\right]$$

$$\sigma_2 = \sigma_y = -p_{max}\left[\left(\frac{1+2\propto_b^2}{\sqrt{1+\propto_b^2}}\right) - 2|\propto_b|\right]$$

$$\sigma_3 = \sigma_z = -p_{max}\frac{1}{\sqrt{1+\propto_b^2}}$$

Where, $\propto_b = z/b$ is non dimensional depth below the surface.

The maximum shear stress is calculated as

$$\tau_{max} = \frac{\sigma_x - \sigma_z}{2} = \frac{\sigma_y - \sigma_z}{2}$$

These equations are plotted as a function of maximum contact pressure up to a distance 3b below the surface contact point, the plot as shown in Fig-3 below is generated. Considering a Poisson's ratio of 0.3, this plot reveals that $\tau_{max}$ becomes maximum for $\propto_b = z/b = 0.786$ and $0.3p_{max}$

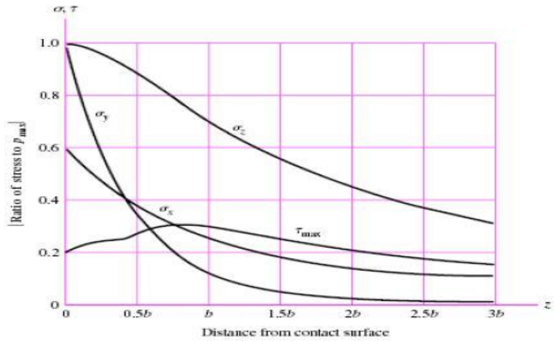


**Fig-3:** Magnitude of stress components below the surface as a function of maximum pressure for contacting bodies

Substituting all the values and computing the stress values we get the following results

$$\sigma_1 = \sigma_x = -18.76\text{MPa}$$
$$\sigma_2 = \sigma_y = -11.95\text{ MPa}$$
$$\sigma_3 = \sigma_z = -50.60\text{ MPa}$$
$$\tau_{max} = 15.92\text{ MPa}$$

## 2. Finite Element Analysis

Finite Element Analysis of this contact point is carried out in ANSYS workbench. The IGS model was imported as model geometry from CATIA software. Contact pressure and maximum shear stress are analyzed from numerical results and compared with analytical results. Fig-4 shows the meshed roller and pallet with fine mesh created at the contact interface.

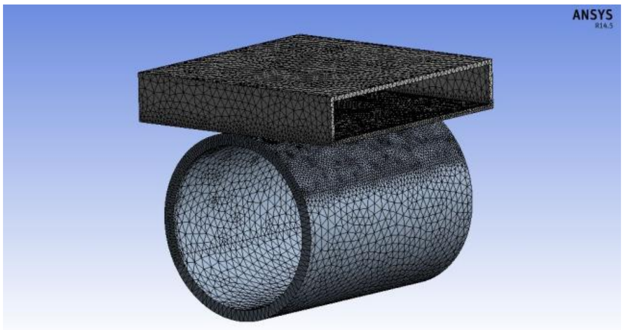


**Fig-4:** Meshed roller and pallet

The load of 450 N is considered to be applied gradually and the roller is fixed about its rotation axis by a fixed joint. The displacement of the pallet is constrained along the X and Y axis and the pallet is allowed to move freely along the Z axis.

The contact status of the roller and pallet is as shown in Fig-5 below with different colored bands indicating the same.

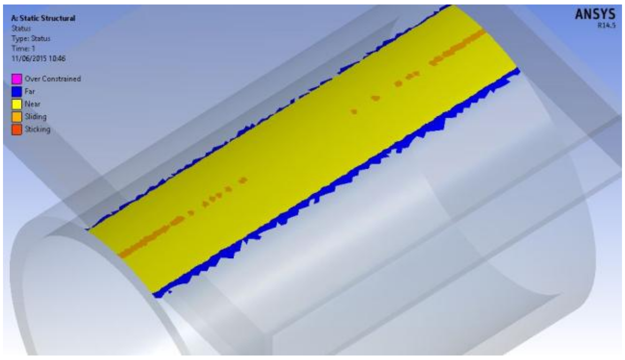


**Fig-5:** Contact status between the pallet and roller

## 2.1 Stress and Pressures developed in roller and pallet

The various stresses and pressures developed are as shown in the figures below.

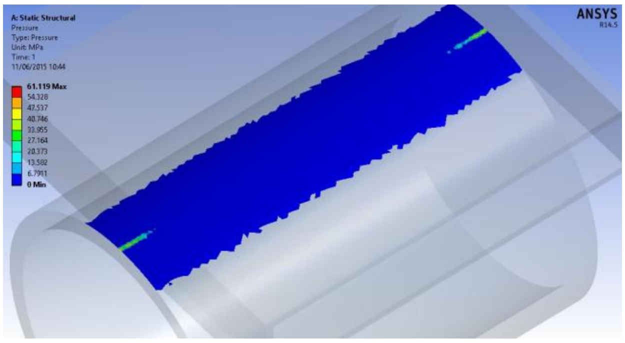


**Fig-6:** Maximum contact pressure

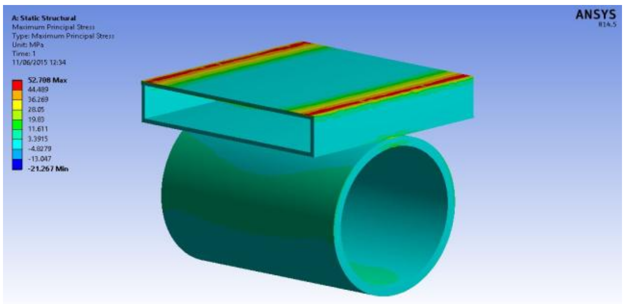


**Fig-7:** Maximum principal stress

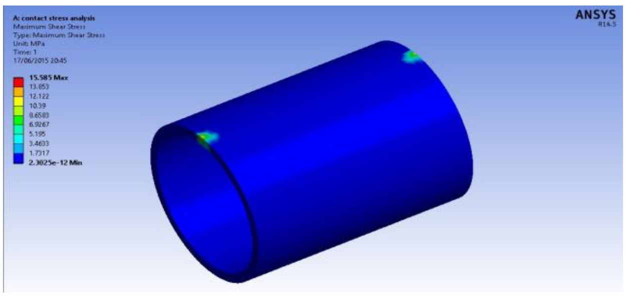


**Fig-8:** Maximum shear stress

 

## 3. Results and Discussions

The comparison between the theoretical and analytical results shows that the FEA results are acceptable. The difference between the results is within 10%. The difference in results is due to the approximation made as i.e. considering only the region where the contact occurs. The value of contact stress is very important, as the stress value changes with contact area. Higher the contact area the stress values will be less and for lesser contact area the stress values will be higher. The contact stress between the roller and pallet is important in order to ensure the stress generated is within the elastic limits, this also helps in predicting the fatigue life by plotting the value of stress in S-N (stress v/s number of cycles) curve of the material. Based on required fatigue life the stress values can be optimized by modifying permissible load carrying capacity or by changing the dimensions of pallet and roller. The comparison of various results is as shown in Table-1 below.

**Table -1:** Comparison of various results

| Description | Theoretical result (MPa) | FEA result (MPa) | Error (%) |
|---|---|---|---|
| Maximum contact pressure | 64.36 | 61.12 | 4.9 |
| Maximum principal stress | 50.60 | 52.70 | 3.9 |
| Maximum shear stress | 15.92 | 15.50 | 2.7 |

## 4. CONCLUSIONS

Contact stress analysis is very important because high localized stress is generated which will lead to fatigue of component. Finite Element Analysis is done in ANSYS Workbench in which contact pressure and shear stresses in roller contact area are analyzed. As this value is below yield limit of material the plastic deformation will not be occur.

## REFERENCES

[1] Wikipedia article, “Contact Mechanics” available in web at http://en.wikipedia.org/wiki/Contact_mechanics.

[2] John A. Williams(Cambridge University), Rob S. Dwyer-Joyce(The University of Sheffield), “Contact between Solid surfaces”,

[3] J.E. Shigley, C.R. Mischke, R.G. Budynas Mechanical Engineering Design, 7th Ed. pp 161-166, McGraw Hill, 2004.

[4] Mr. Prabhakar Purushothaman, Dr. Prashant Thankachan, “Hertz Contact Stress Analysis and Validation using Finite Element Analysis, IJRASET, Volume 2 Issue XI, November 2014.

[5] Nortan, R.L., Machine Design: An Integrated Approach, 2nd Edition, Prentice Hall.

[6] Nicholas LeCain, “Tutorial of Hertzian Contact Stress Analysis” College of Optical Sciences, University of Arizona, Tucson, pp-1 to 6, 3 Dec 2011.

[7] ANSYS Workbench 14.0 for Engineers and Designers, Prof. Sham Tickoo, Dreamtech Press, 2013.

 