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Analysis of Calcination Drums under Static and Dynamic Conditions

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Abstract: ***Solid waste management is posing a great problem as the population is increasing day by day. The municipal sewage waste has to be disposed properly otherwise it will lead to air pollution and cause the serious effects on the health of human beings. The most common practice adopted is generating methane from municipal solid waste. For this purpose it is necessary that the municipal solid waste which is sent for further processing should be in the form of homogenous mass. In order to form the homogenous mass it is necessary that it should be separated in degradable and non degradable. This degradable waste is then converted into fine particles. To achieve this task the engineers have designed a special instrument named Calcination Drum. Usually Calcination Drum is also known as Rotary Kilns. In primary stage when the Calcination Drum was implemented it was found that some problems were encountered. The main aim of this project is to solve the problems related to guide ring and support roller shaft of Calcination Drum. Analysis of roller shaft, roller and Calcination drum is carried out and the stress as well as deformation is found out in static and dynamic condition. For theoretical calculations of shaft the standard data is taken from design data book and for guide ring Hertz contact stress theory is used.***

Keywords: Calcination Drum, Support Roller Shaft, Guide ring, Roller, ANSYS software

1. Introduction

Solid waste management is becoming matter of great concern due to increasing population. Generally in most cities one common method is adopted for waste disposal i.e. dumping on the grounds present outside the cities. If the non degradable wastes are not dumped properly then it may cause the severe effects like air pollution, diseases etc; considering all these ill effects it is necessary that the wastes should be dumped properly after segregation (degradable and non degradable). It is obligatory on each municipal corporation that proper remedies should be adopted for disposing of municipal solid wastes.

The mostly adopted method for disposing the wastes is the methane generation. For that purpose it is required that the municipal solid waste should be in the form of homogenous mass. In order to create the homogenous mass the Calcination drum was developed.

2. Construction of Calcination Drum

Fig 1 shows the typical construction of Calcination drum. This type of construction has variety of applications like drying, dehumidification, cement, ore-processing and chemical etc. The drum shown in above fig consists of a cylindrical shell slightly inclined from the horizontal position and supported by guide-rings (often called tires) riding on the pair of rollers. A gear rim and pinion assembly rotates the entire system. Material enters the drum at upper end and moves towards the lower end with continuous mixing and 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 firebrick lining to protect the steel outer shell from the high temperature existing inside. The ride ring or guide ring is a cylindrical tire connected to the shell and rotating with it. Economies of scale in the cement and ore processing industries have led to manufacturing of large diameter units resulting to loads of several hundred tones carries by the ride rings. The rings themselves weigh several tens of tons. As units become larger, it is important to review existing practices and determine rationally the proper selection of design quantities so that maximum efficiency and minimum cost may be achieved.

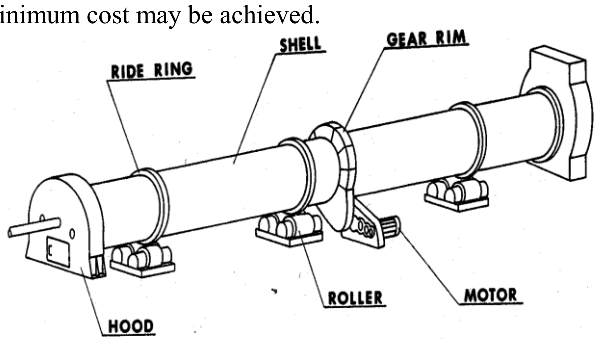

Figure 1: Construction of Calcination Drum

Figure 2: Actual Setup of Calcination Drum

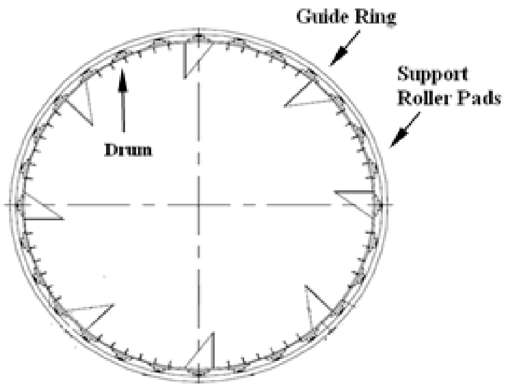

Figure 3: Location of guide ring on the drum

3. Problems encountered in implementation of Calcination Drum

3.1 Failure of support roller unit assembly.

a) Failure of support roller shaft.
b) Failure of support roller shaft bearing.

3.2 Failure of support roller guide ring assembly.

a) Failure of guide ring.
b) Failure of guide packing's and ovality with center axis.
c) Cracks are developed on the support guide ring.
d) Uneven thickness observed on the support guide ring.
e) Failure of welding joints.

3.3 Failure in alignment

Alignment of calcinations drum and support structure assembly is mismatched due to wear between the guide ring and roller. The wear may take place due to following common situations:

1) Support Rollers are improperly set, such that the centerline of the Drum is not on the same slope as the Support Rollers and Bases.
2) Support Rollers are not on the proper slope due to deformation of the Bases. Pier movement, improper shimming, and/ or Base Shim corrosion and Grout failure.
3) Support Roller Bases are not at the proper elevation due to Pier settlement.
4) Tapered wear due improper skewing of the Support Rollers.
5) Tapered wear due to Tire axial run out.
6) Wear due to excessive Gear /Pinion backlash.

Vertical Offset

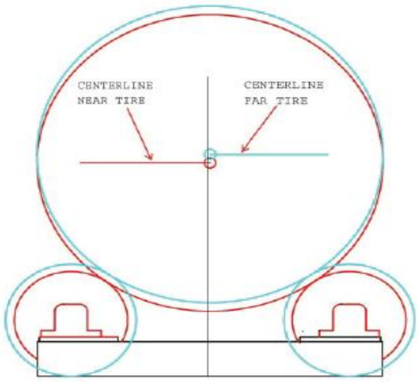

Figure 4: Vertical Offset

If the Support Rollers are on the correct slope, but are misadjusted in such a manner that the centerline of the front guide ring (tire) is higher or lower than far tire, the slope of the Drum will be different than the Support Rollers, and tapered wear condition will occur.

Horizontal Offset

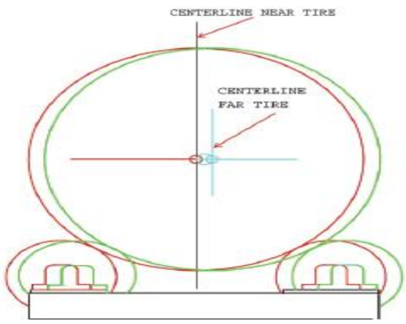

Figure 5: Horizontal Offset

If the Support Rollers are on the correct slope, but are misadjusted in such a manner that the centerline of the near tire is right or left of the far tire; a whirling action will occur. Sometimes resulting taper is in two directions across the face of the Tire and Support Roller.

3.4 Calcination Drum Body problems

a) Because of uneven concentration of sewage waste weight in the drum, there are some difficulties found to maintain the concentricity with structure axis.
b) Thickness of plate selected to fabricate the Calcination drum is needed to be redesigned and analyzed.

3.5 Design problems with supporting structure

Alignment of Calcination drum and support structure assembly is mismatched.

3.6 Design problems involved with gear drive:-

a) Cracks developed on the gear ring.
b) Same problems are involved which are encountered by support guide ring.

In our dissertation work we have focused on solving the problems related to guide ring and roller.

4. Calculation of Contact Stresses in Guide Ring

In mechanical engineering and tribology; Hertzian contact stress is a description of the stress within mating parts. This kind of stress may not be significant most of the time but may cause serious problems if not take into account in some cases. This tutorial provides a brief introduction to the Hertzian contact stress theory.

Theoretically, the contact area of the two spheres is a point, and it is a line for two parallel cylinders. As a result, the pressure between two curved surfaces should be infinite for both of these two cases, which will cause immediate yielding of both surfaces. However, a small contact area is being created through elastic deformation in reality, thereby limiting the stresses considerable. These contact stresses are called Hertz contact stress usually refers to the stress close to the area of contact between two spheres of different radii. In our problem we are considering the roller and guide ring as two cylinders in contact with each other whose axis are parallel to each other as shown in diagram below.

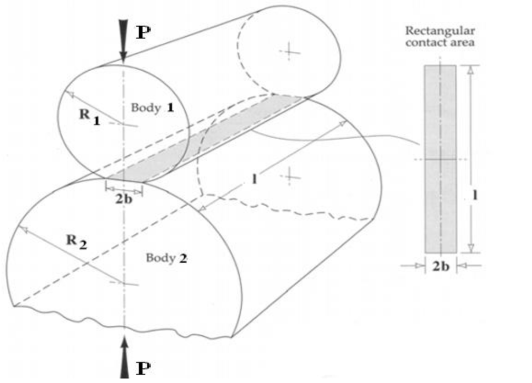

Figure 6: Contact stresses between two cylinders

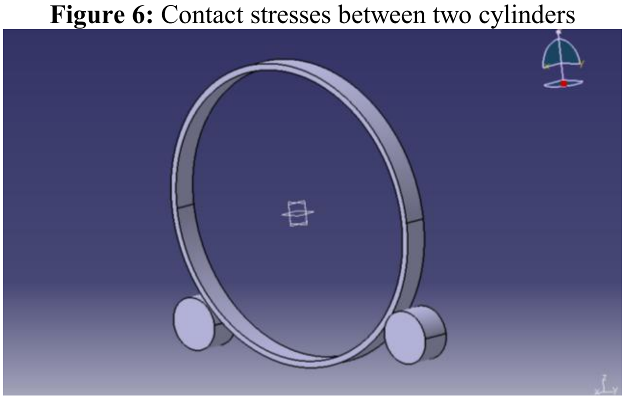

Figure 7: Guide Ring and Roller Assembly

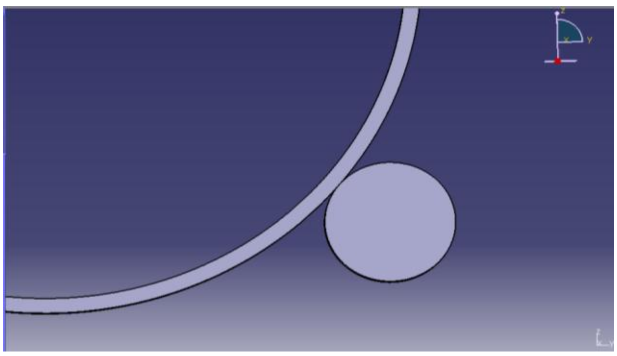

Figure 8: Contact between Guide Ring and Roller

According to Hertz contact stress theory the width of the contact area between the two cylinders is given by

$$b = \sqrt{\left(\frac{2F}{\pi \times l} \times \frac{\frac{(1-\vartheta_1^2)}{E1} + \frac{(1-\vartheta_2^2)}{E2}}{(\frac{1}{d_1} + \frac{1}{d_2})}\right)} \quad \text{.........(1)}$$

The maximum contact pressure for similar material is given by

$$P_{max} = 0.418\left(\frac{PE}{l}\left(\frac{1}{R_1} + \frac{1}{R_2}\right)\right)^{\frac{1}{2}} \quad \text{.........(2)}$$

(Referred from PSG Design Data Book Page No 7.18)
The average contact pressure is given by

$$P_{avg} = \frac{P}{4.b.l} \quad \text{.........(3)}$$

Maximum shear stress is given by

$$\tau_{max} = 0.30 \times P_{max} \quad \text{.........(4)}$$

$$Z = 0.79 \times b \quad \text{.........(5)}$$

b = Half width of deformation
P = Normal load
E_1, E_2= Modulus of Elasticity of cylinder 1 and 2 respectively
ϑ_1, ϑ_2= Poisson's Ratio of cylinders 1 and 2 respectively
D_1, D_2 = Diameter of guide ring and roller respectively
l= Length of contact between two cylinders
Z = Depth at which maximum shear stress is induced
The material used for roller and guide ring is same i.e. MS
Hence values are taken as follows:
$E_1 = E_2 = 2 \times 10^5\ MPa$
$\vartheta_1 = \vartheta_2 = 0.3$
The dynamic load is distributed among the 4 rollers who are aligned at 50˚.Hence load acting at contact area is nothing but the vertical component of load which is given by

$$P = \frac{W}{4} \times \cos\theta$$

$$= \frac{160 \times 1000 \times 9.81}{4} \times \cos 50 = 252229.85\ \text{N}$$

$D_1 = 3679.24$ mm
$D_2 = 640$ mm
$L = 275$ mm
The contact width between two cylinders is given by

$$b = \sqrt{\left(\frac{2 \times 252229.85}{\pi \times 275} \times \frac{\frac{(1-0.3^2)}{2\times10^5} + \frac{(1-0.3^2)}{2\times10^5}}{(\frac{1}{3679.24} + \frac{1}{640})}\right)}$$

b= 1.701 mm
The maximum pressure induced can be calculated by substituting the values in equation no (2).

$$P_{max} = 0.418\left(\frac{252229.85 \times 2 \times 10^5}{275}\left(\frac{1}{1839.62} + \frac{1}{320}\right)\right)^{\frac{1}{2}}$$

Pmax =342.90 MPa

The two contacting surfaces can withstand the stresses as long as the surface compressive (endurance) strength is greater than the maximum stress acting on the contact area.

The surface endurance strength of the material is given by

$$\sigma_c = 0.27 \times 9.81 \times BHN$$

For the steels the Brinell hardness number ranges from (197 – 401 BHN) as per given in magazine of Materials 1978 reference issue.

The Brinell hardness number is limited to approximately 500HB. As the material becomes harder there is a tendency for the indenter itself to start deforming and the readings will not be accurate. If we change the indenter we can measure maximum hardness up to 650 HB.

Hence taking mean value i.e. BHN = 310

$\sigma_c =$ 0.27×9.81×310 = 821 Mpa

Pmax <= Surface compressive strength

Hence the design is safe.

The average pressure is calculated by substituting the values in equation no (3)

$$P_{avg} = \frac{252229.85}{4 \times 1.05 \times \frac{275}{2}}$$

Pavg = 167.98 Mpa

The depth at which maximum shear stress occurs is

Z = 0.79× 1.701 = 1.34 mm

The maximum shear stress induced is obtained by substituting values in equation (5)

$$\tau_{max} = 0.304 \times 342.90 = 104.24 N/mm^2$$

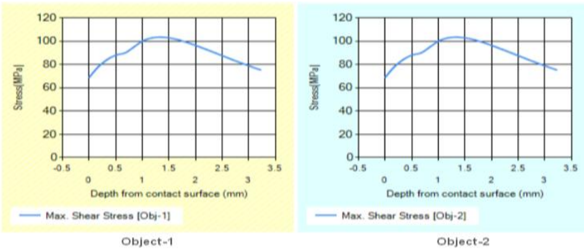

Figure 9: Graph of maximum shear stress in two cylinders

5. Analysis of Drum in static condition

The material of drum is MS. The element chosen for analysis is solid 185.

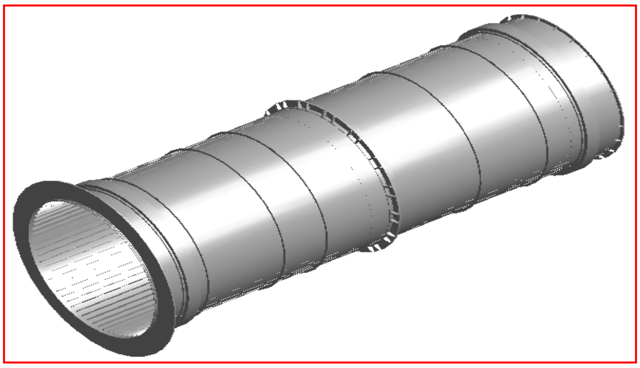

Figure 10: Geometry considered for analysis

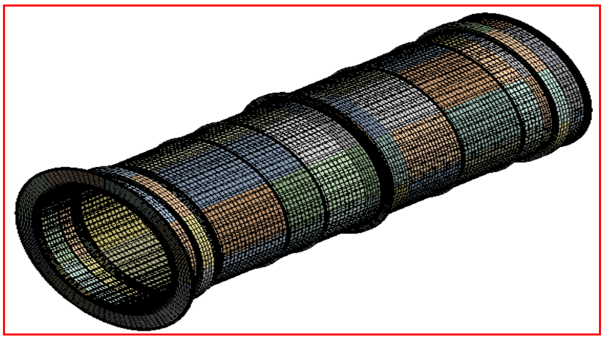

Figure 11: Detailed Meshing of drum

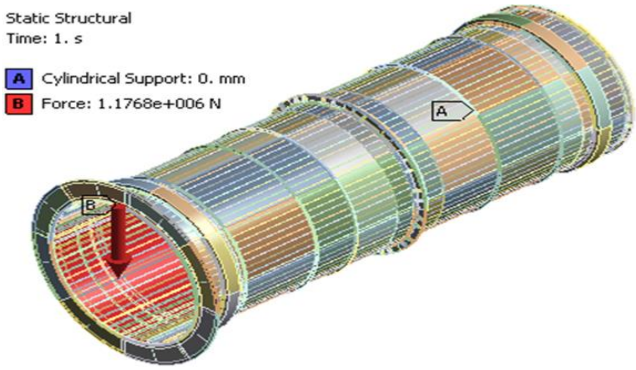

Figure 12: Loading and Boundary Conditions in Static condition

Fig 12 shows the loading and boundary conditions. Load of 120 ton is acting in downward direction shown by downward arrow (shown in red color).The drum is supported by 4 rollers at 4 locations.

5.1 Total Deformation plot of Calcination Drum

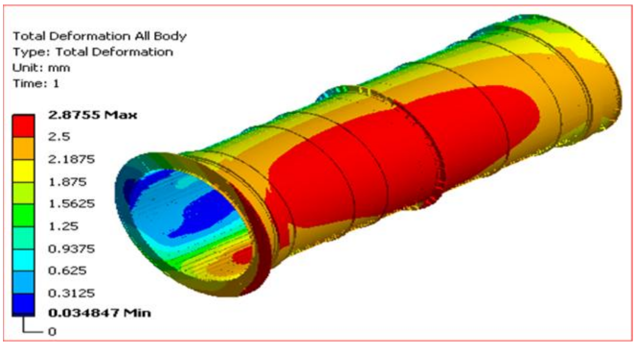

Figure 13: Total Deformation of Calcination Drum under Static condition

Fig 12 shows the deformation in the Calcination Drum. The red zone shows maximum deformation i.e. 2.8755 mm. From fig we can see that the deformation is maximum at the top side and it goes on decreasing as we go in downward direction.

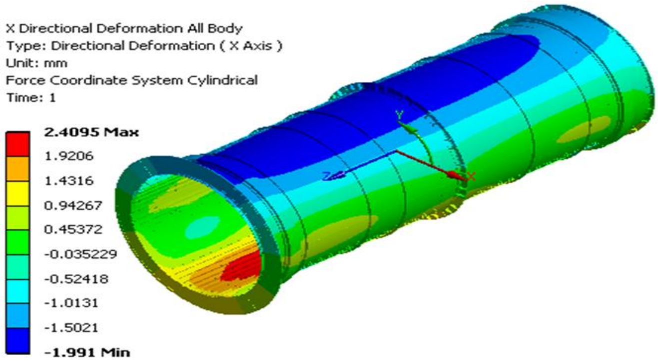

Figure 14: Directional Deformation of Calcination Drum under Static condition

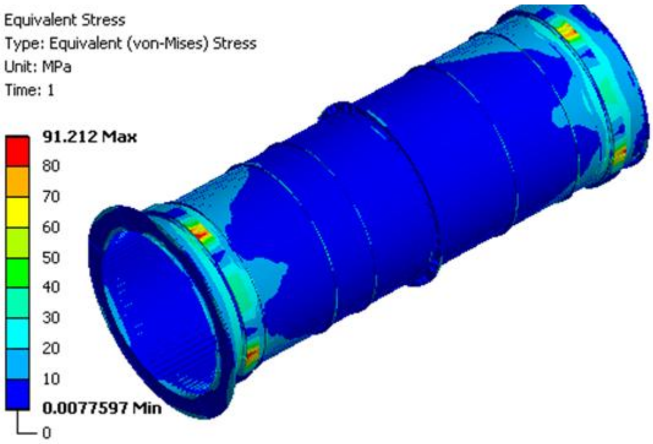

Figure 15: Von-Mises Stress in Calcination Drum in Static condition

Dynamic loading rotating conditions

The fig 15 shows stress distribution throughout the Calcination drum. The stress concentration zone is shown as exaggerated view in alongside image. The maximum stress found was 91.212 MPa.

6. Analysis Results of Calcination Drum (Dynamic Loading Rotating Condition)

From Static loading from Stresses we can observe that Un-symmetric loading is critical loading hence only Rotating Condition is considered in Dynamic Loading.

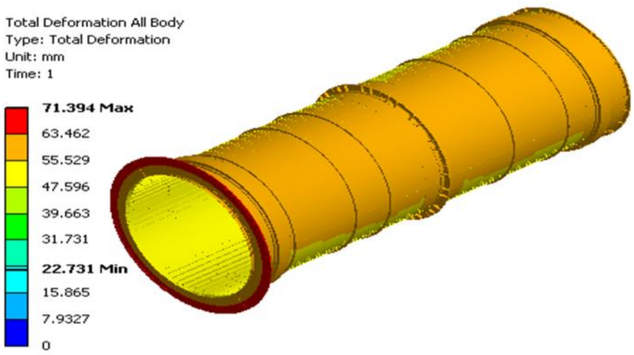

Figure 16: Total Deformation in Calcination Drum under

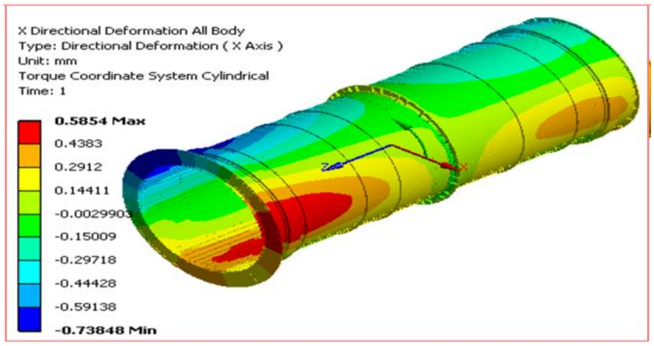

Figure 17: Directional Deformation in Calcination Drum under Dynamic loading rotating condition

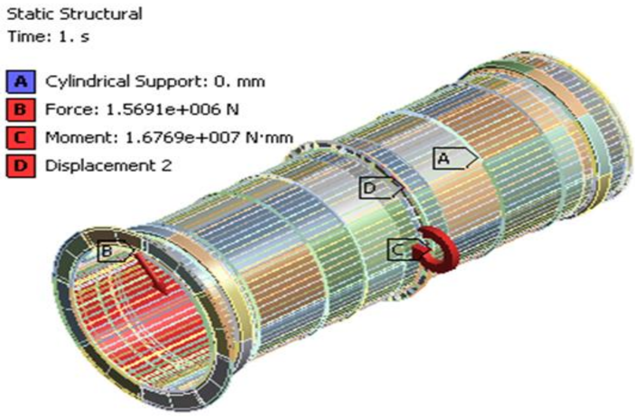

Figure 18: Loading and Boundary Conditions under Dynamic loading rotating condition

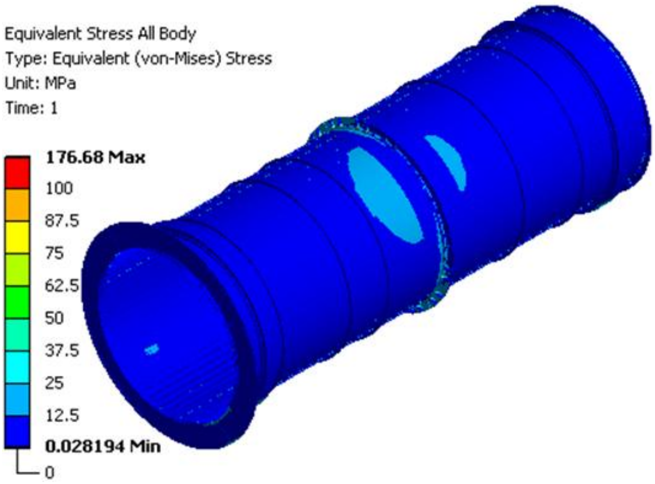

Figure 19: Von Mises Stress in Calcination Drum under Dynamic loading rotating condition

From the Fig 19 it is seen that the maximum value of Von-Mises stress is 176.68 MPa. This value is much more less than our yield stress.

7. Calcination drum ANALYSIS Results

7.1 Calcination drum under Static loading condition

Sr. No	Deformation (mm)	Von-Mises Stress(MPa)
1	2.8755	91.212

7.2 Calcination drum under Dynamic loading rotating condition

Sr. No	Deformation (mm)	Von-Mises Stress(MPa)
1	0.5854	176.68

8. Conclusion

- Maximum Deformation in the model is found to be 3.7 mm.
- Maximum Stress in the Drum are found to be 176.68 MPa which is less than the Yield Strength of Material hence Design is Safe for given Loading & Boundary Conditions .
- Based on the analysis performed, results seen are safe in terms of stresses as well as deflection. Since worst loading condition may not be regular, the design is safe.

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