Static Analysis of Three Roller Conventional Crushing Mill

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Abstract- *Sugarcane roller mill is the vital part of sugar industry. The main objective of milling is to separate the sucrose-containing juice from the cane. The extraction of juice in a mill is achieved by squeezing prepared cane between two rolls. Finite Element Method is a numerical technique used to carry out the stress analysis. In this method the solid model of the component is subdivided into smaller elements, constraints and loads are applied to the model. Geometrical model is created using 3D modeling software Creo. The static analysis of each component is carried out using analysis software ANSYS WORKBENCH. The results for maximum shear stress on the top, feed, discharge roller are calculated. Static analysis of all three rollers is done using different materials for analyzing the variation in results.*

Keywords- Crushing roller, Static analysis, Max. Shearstress theory, ANSYS Workbench.

I. INTRODUCTION

The main objective of milling is to separate the sucrose containing juice from the cane. The extraction of juice in a mill is achieved by squeezing prepared cane between two rolls. In three roller mill three rollers are arranged in triangular pattern for removing sucrose 90-95%. These rollers are fed by two pressure feeder rollers which take prepared cane from a vertical chute and may be assisted byan under feed roller at the exit from the chute. The arrangement of rollers in three roller mill is as follows-

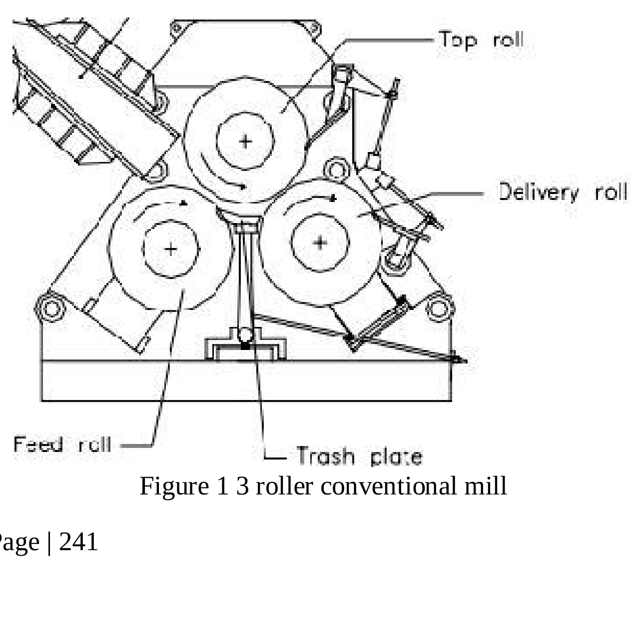
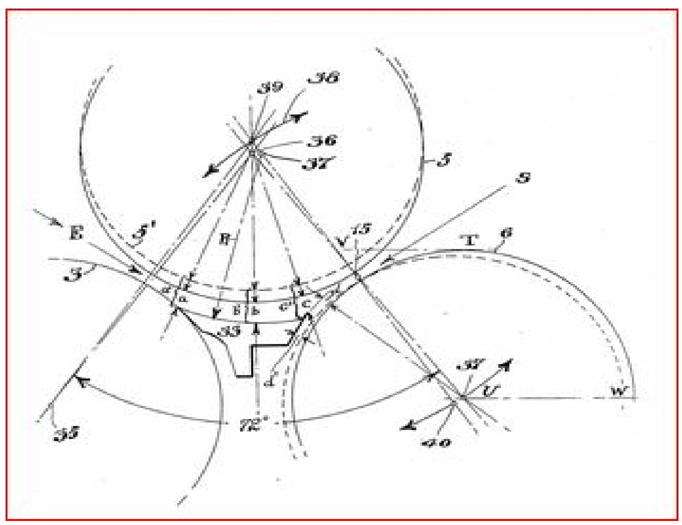


Figure 1 3 roller conventional mill

Three rollers are used named as top, feed & discharge roller. The rollers are arranged in an isosceles triangle with a top angle of 720. The feed and discharge rollers are placed at an angle of 35 & 37 respectively from the vertical be low the top roller. The crushing of cane takes place first in top-feed roller and then in top-discharge roller. The shaft of roller is made up of forged steel and shell of the roller is made up of cast iron. The shell is shrink fitted on the shaft.

The power for crushing of sugarcane is given to the top roller which rotates feed and discharge roller with arrangement of pinion attached on one side of roller. The direction of rotation of top and feed – discharge rollers is opposite. The steam turbine power is given to the top roller for crushing.

Top roller is critical component amongst all. As the drive torque, hydraulic load, crushing load is coming on the top roller. The forces acting on the mill rolls give rise to shearing, bending, torsion and compressive stresses. The top roller is most highly stressed, since it consumes about half of the mill torque. Out of total power 50% is taken by top roller, 35% is taken by discharge roller, 15% is taken by feed roller.



II. LITERATURE REVIEW

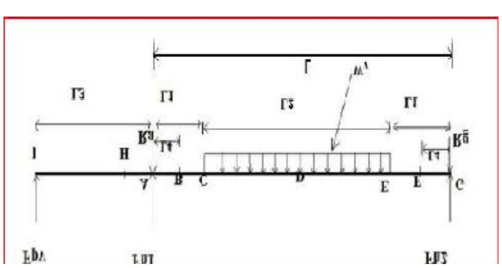
AUTHOR	*TITLE*	*PUBLICATION*	*CONCLUSION*
1Mr. Tagare V.S, 2Mr. Patil V.B 3Mr. Talaskar S.P,	*Design and manufacturing of sugar cane peeling machine*	*International journal of advanced scientific and technical research*	*> The cost of production and maintenance is relatively cheap.*
Santosh Y. Salunkhe	*Static Structural Analysis of Conventional Sugar Mill*	*International Journal of Latest Trends in Engineering and Technology*	*>Max stress for all three roller is less than yield strength so all three roller are safe.*
Shinde V. V, Swami M.C	*Weight Reduction and Analysis of Sugar Mill Roller Using FEA Techniques*	*International Journal of Latest Trends in Engineering and Technology*	*>Two sugar roller mill with hollow shaft is preferable one and it offers much greater safety factors against failures.*

III. APPROACH

Calculation for 3 roller conventional mill roller

The top roller is most highly stressed, since it consumes about half of the mill torque. The forces on the top roller are because of power transmission, crushing, and hydraulic load. The loads on the roller are divided into horizontal and vertical component of loading.

Top roller details
Power(p)= 750 hp
Roller Speed (n) = 4-5 rpm
Roller diameter= 987mm
Shaft diameter at roller=510mm
Shaft diameter at bearing support=460mm
Shaft dia. at pinion=500mm
Pitch circle dia. of crown pinion= 760 mm



L1=824.5mm
L2=1981 mm
L3=630mm
L4=3630mm
Total length of shaft L=3630mm

Driven torque = $\frac{hp*4500}{2*3.14*n}$

=1054.0587KNmm

Out of total torque 50% is taken by top roller

So torque on top roller = 527.029KNmm

Tangential component (horizontal) of torque due to force

(FPh) = $\frac{torque*2}{P.C.D}$
=1386.91 KN

Radial component(vertical) of force due to torque
(FPv)=sin55*torque
=431.71KN

The load of crushing from discharge roller is acting at an angle of 53 from right side =550 tones
=5500KN

The vertical component of load =sin53*5500
=4505.3362KN

The horizontal component (left)=cos55*5500
=3309.982KN

The load of crushing from feed roller is acting at an angle of 55 from left side =210tons =2100KN

Vertical component of load =1720.219 KN
Horizontal component of load= 1204.510 KN
Total vertical load acting on roller =6225.5552KN
Total horizontal load acting on roller =4514.492KN

The load of crushing is acting on the surface of roller so it will be shown as uniformly distributed load (U.D.L) on loading diagram.

Intensity of U.D.L in vertical loading diagramWv=total vertical load due to crushing/length of shell of roller
=6225.5552/3630
=1.7150KN/mm

Intensity of udl in horizontal loading diagram Wh=1.2436KN/mm

Diameter of the hydraulic ram=350mm

Total hydraulic load acting on top roller =2*area of piston*oil pressure

= (2*6.28*3.14(460*460)*2.35)/4

= 4519.637KN

= 4520 KN

Hydraulic load acting on bearing =2260KN

THREE DIMENSIONAL CREO MODEL

A three dimensional model of crushing roller is made by using modeling software CREO.

All three rollers i.e. top, feed and discharge roller having same dimension and geometry.

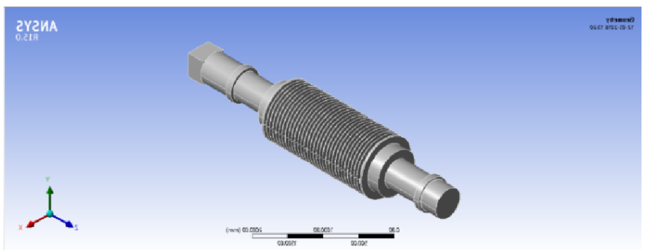


Figure 1 3-D model of roller

Static Analysis of Top Roller:-

Static analysis of top roller is done for observing maximum stresses and deformation of roller when different forces such as crushing, hydraulic, torque due to power transmission etc. Are applied on it. Static structural analysis is done using ANSYS WORKBENCH.

Mesh Generation

The CREO model in IGES format is imported in ANSYS Workbench. Meshing is performed in the same software.

Meshing is the process of converting the model into number of discrete parts called as element.

The element is defined by 10 nodes having three degree of freedom a teach node translations in the nodal X, Y, and Z direction. Fine meshing is done at the portion where stress is maximum. Total 69638 node and 40488 element are obtain from meshing.

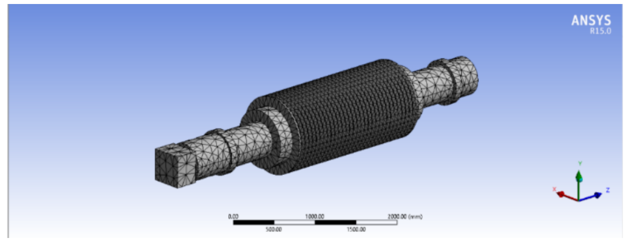


Figure 2 meshing

Loading And Boundary conditions:-

Boundary condition: - As roller is simply supported so all degrees of freedom of roller are fixed at the bearing position.

Loading Details:-

The horizontal and vertical component of loads due to crushing are applied on roller shell as uniformly

Distributed Load (U.D.L).

Total vertical load= 6225.5552 KN (up)

Total horizontal load= 4514.492 KN (left)

The Tangential (horizontal) and Radial (vertical)components of load due to power transmission are applied at pinion end of roller.

Tangential Component = 1386.91 KN

Radial Component = 431.71 KN

Hydraulic load is applied at the bearing position. Which is 2260KN

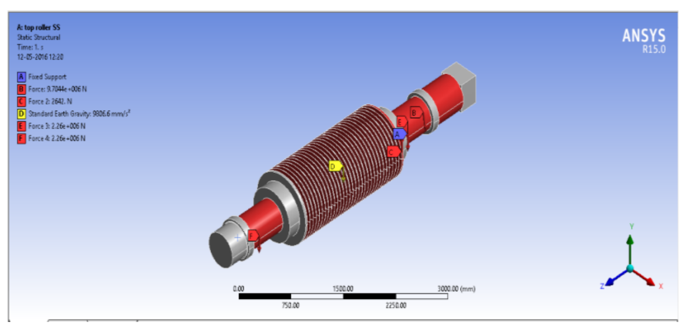


Figure 3 force distribution on roller

Material Properties:-

Material for Crushing roller shaft is structural steel.

Material: - structural steel

Density: - 7850 Kg/m3

Modulus of Elasticity:- 200GPa

Poisson’s ratio: - 0.3

Tensile yield strength: - 250 MPa

Tensile ultimate strength: - 460Mpa

4) Results of static analysis for top roller:-

Maximum shear stress, Total deformation are calculated as Static analysis results. Shown in below figures-

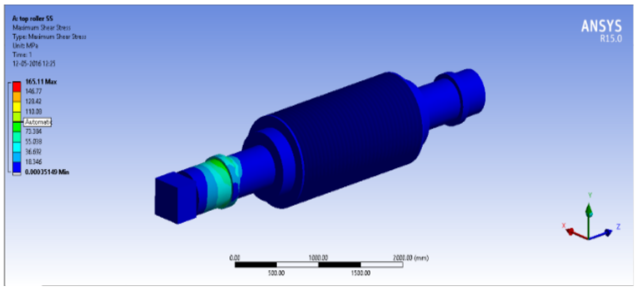


Figure 4 stress on top roller

Maximum value of shear stress is 105.11 MPa which is at bearing position of top roller. Maximum value of shear stress is within limit so shaft is safe. Minimum value of shear stress is 3.514e-4 MPa at bearing, shell and pinion end.

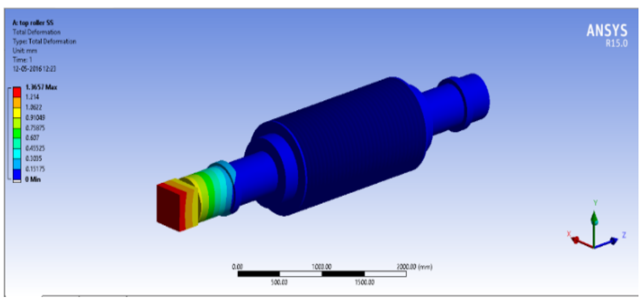


Figure 5 total deformation on top roller

Maximum value of total deformation is 1.3657 mm at the pinion end of top roller, which is within limit. Minimum value of deformation is 0 mm which is at bearing position.

Static Analysis of Discharge Roller:- model, meshing, material, boundary conditions are same as that of top roller.
The horizontal and vertical component of loads due to crushing are applied on roller shell as uniformly

Distributed Load (U.D.L).
Total vertical load= 4505.3362KN (down)
Total horizontal load= 3309.982 KN (right)
The Tangential (horizontal) and Radial (vertical)components of load due to torque are applied at pinion end of roller.
Tangential Component = 0.9710 KN
Radial Component = 211.649 KN
Standard earth gravity (self-weight is applied).

Static analysis of discharge roller

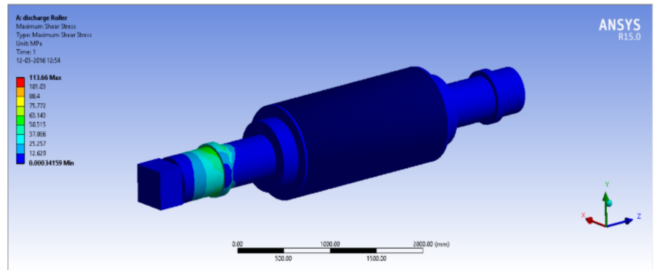


Figure 6 stress on discharge roller

Maximum value of shear stress is 113.66 MPa which is at bearing position of discharge roller. Maximum value of shear stress is within limit so shaft is safe. Minimum value of shear stress is3.4159Me-4 at bearing, shell and pinion end.

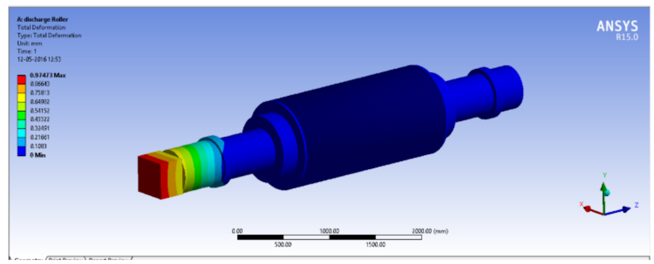


Figure 7 total deformation on discharge roller

Maximum value of total deformation is 0.977473 mm at pinion end of discharge roller.

Static Analysis of Feed Roller:-model, meshing, material, boundary conditions are same as that of top roller.

The horizontal and vertical component of loads due to crushing are applied on roller shell as Uniformly Distributed Load (U.D.L).

Total vertical load= 1720.219KN (down)
Total horizontal load= 1204.510 KN (left)
The Tangential (horizontal) and Radial (vertical)components of load due to torque are applied at pinion end of roller
Tangential Component = 415.78 KN
Radial Component = 129.42 KN
Standard earth gravity (self-weight is applied).

Static analysis for feed roller

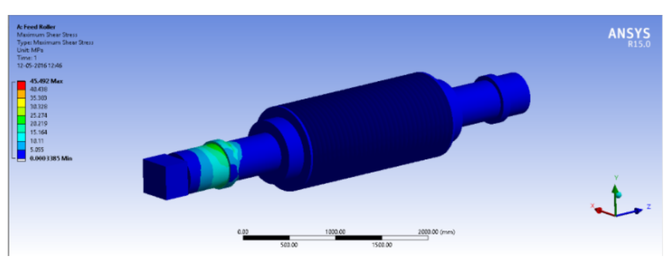


Figure 8 stress on feed roller

Maximum value of shear stress is 45.492 MPa which is at bearing position of feed roller. Maximum value of shear stress is within limit so shaft is safe. Minimum value of shear stress is 3.385e-4 MPa at bearing, shell and pinion end.

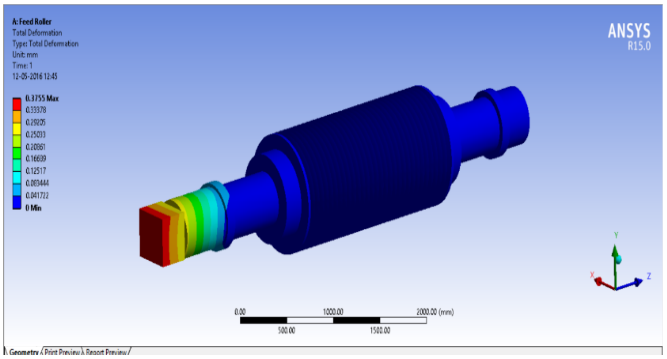


Figure 9 deformation on feed roller

Maximum value of total deformation is 0.3755 mm at pinion end of Feed roller.

IV. STATISTICAL RESULTS OF TOP FEED AND DISCHARGE ROLLER

Top roller

SR NO	MATERIAL	TOTAL DEFORMATIO mm	SHEAR STRESSM pa	MASSk g
1	STRUCTRAL STEEL	1.3657	165.11	1518
2	ALLUMIUMALLOY	3.8256	165.23	5356
3	TITANIUM ALLOY	2.8143	165.57	8933.2

Table 2 top roller stress analysis for different material

Feed roller

SR NO	MATERIAL	TOTAL DEFORMATION(mm)	SHEAR STRESS(Mpa
1	STRUCTRAL STEEL	0.3755	45.492
2	ALLUMIUMALLOY	1.0485	45.406
3	TITANIUM ALLOY	0.77211	45.539

Table 3 feed roller stress analysis for different material

Discharge roller

SR NO	MATERIAL	TOTAL DEFORMATION(mm)	SHEAR STRESS(Mpa)
1	STRUCTRAL STEEL	0.9743	113.63
2	ALLUMIUMALLOY	2.7295	113.69
3	TITANIUM ALLOY	2.0079	113.94

Table 3 discharge roller stress analysis for different material

V. CONCLUSIONS

Based on the total deformation and cost of rawmaterials, forged steel is the best among givenmaterials. As material is a changed value of max. Shear stress isnearly same

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