Weight Reduction and Analysis of Sugar Mill Roller Using FEA Techniques

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Abstract: The basic three-roller mill designed and developed in early 1900s incorporated two compressions in the mill with high frictional work between compressions over the trash plate. Three roller mills which are used for extraction of juice consist of three rollers i.e. Top, Feed and Discharge rollers. Sugarcane is being fed into top and feed rollers which further passes through top and discharge roller along with trash plate. This trash plate is having a downside that 25% of total hydraulic load is shared by this trash plate in overcoming friction and remaining 75% only the useful one, i.e. 25% hydraulic load is shared by feed roller and 50% is shared by discharge roller Today, heavy-duty shredders and fibrizors prepare the sugarcane with up to 90% open cells before it is fed to the mills. As a result, frictional work over the trash plate is no longer necessary, so eliminating the trash plate was an obvious choice for engineers. Considering above pitfalls two roller mills can be the best option because it doesn't require trash plate and any trash plate adjustment and replacement. Two roller mills consist of only two rollers i.e. top and bottom roller. 100% of hydraulic load is available for compression at bottom roller. Hydraulic load required is 70% of same size conventional 3-roller mill which is not shared and directly transferred to the bottom roller. 2-roller has better drainage because of its simplicity; capital cost is 12% less than traditional mill, no slippage and less juice absorption by bugasse. In this, shaft of bottom roller is a critical part which should be designed.

Index Terms— roller mills,FEA.

I. INTRODUCTION

Harvested sugar cane from the fields is piled, picked up, tied, and transported to the sugar factory by trucks. In the plant, a cane carrier carries the cane to the preparatory devices such as Kicker, Leveler, and Shredder, where the cane is cut into pieces and the prepared cane is fed into the milling tandem to extract the juice. The material left after extracting the juice is called bagasse and is used as fuel in the boilers for steam generation. This steam generated is used in the turbine to generate power. Part of the steam from the turbine is used for process heating requirements.

While the current system uses two choppers and one shredder, the proposed has one chopper and one shredder. In both cases, prepared cane feeds a mill to extract cane juice in 4 crushers in tandem. Each crusher contains three rolls in an isosceles triangle arrangement .A fourth press-roller pre-compresses the cane bed to facilitate extraction. Fig.1.2 is a schematic of the cane juice extraction equipment. The mill produces cane juice (mainly an aqueous solution of sugars) and bagasse (solid residue, mainly fibrous).

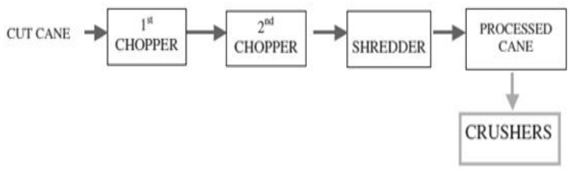


Fig 1.1 Schematic of sugar preparation process

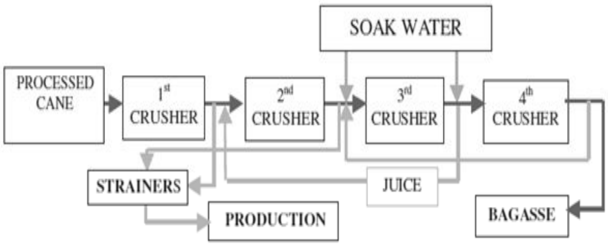


Fig 1.2 Sketch of the cane syrup extraction process

Types of roller mills

a) Two high roller mill
b) Three high roller mill
c) Four high roller mill
d) Six high roller mill
e) Eight high roller mill

Usually three roller mills are used for extraction of juice which consists of three rollers, Feed and Discharge rollers. Sugarcane is being fed into top and feed rollers which further passes through top and discharge roller along with trash plate. This trash plate is having a downside that 25% of total hydraulic load is shared by this trash plate in overcoming friction and remaining 75% only the useful one. i.e. 25% hydraulic load is shared by feed roller and 50% is shared by discharge roller. Crushing rolls are designed with high coefficient of friction and very low rotational (4–5 rpm) speed.

Considering above pitfalls two roller mills can be the best option because it don't require trash plate, no trash plate adjustment and replacement. Two roller mills consist of only two rollers i.e. top and bottom roller. 100% of hydraulic load is available for compression at bottom roller. Hydraulic load required is 70% of same size conventional 3-roller mill which is not shared and directly transferred to the bottom roller. 2-roller has better drainage because of its simplicity; capital cost is 12% less than traditional mill, no slippage and less juice absorption by bugasse. So in sugar industry it is very essential to design 2-roller mill as it has got above advantages and analyzing it with FEA techniques for its safe working. In this, shaft of bottom roller is a critical part which should be designed.

II. THEROTICAL DETAILS

Difference between conventional (Three) roller mill and new two roller mill

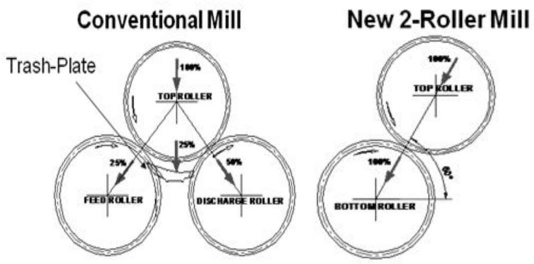


Fig 2.1 Conventional roller mill & New 2-roller mill

In conventional mill,

- Trash-plate absorbs almost 25% of hydraulic load applied on Top Roller.
- Only ~75% of Hydraulic Load utilized for juice extraction.
- 20-25% power loss in dragging the bagasse over trash-plate.
- Unbalance force friction loss due to sliding of top roller.

In new 2-Roller mill,

- No trash-plate, power losses due to trash-plate are saved.

- 100% Hydraulic Load applied on Top Roller utilized for juice extraction.

Input data

- Power (P) = 940 HP; Roller speed= 3.4 rpm; roller dia.= 1270 mm
- Shaft dia. at roller= 660 mm;
- Shaft dia. at bearing support= 620 mm;
- Shaft dia. at pinion= 580 mm.
- Baggase load= 560,000 kgf; Self weight= 40,000 kgf
- Total load= 5886 KN. (Acts vertically)
- Load acting in horizontal direction is calculated as = 775.4 KN
- L1= 605 mm; L2= 2540 mm L3= 890 mm;
  L4= 385 mm; L= 3750 mm.

Calculation for forces acting on Gear (used for power transmission):

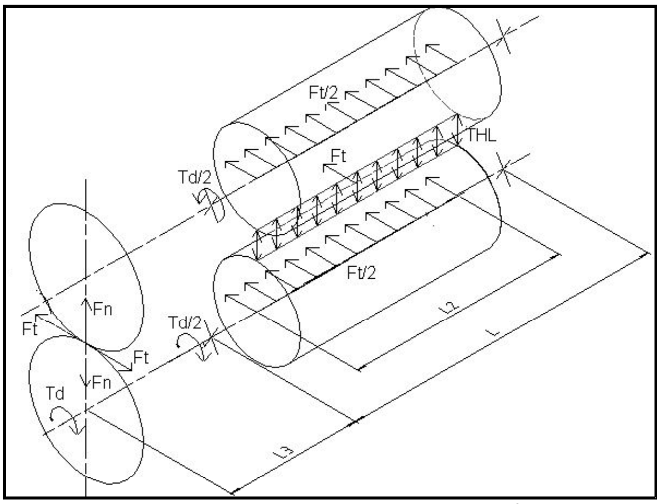


Fig2.2 forces acting on Gear

Transmitted Load/Tangential Load (Ft) acting on Gear Tooth

$$W_t = F_t = \frac{60000 \times P}{\pi d n}$$

$$= \frac{60000 \times 701.24}{\pi \times 1270 \times 3.4}$$

$$F_t = 3101.6\,KN$$

Radial or Normal Force Fr (Shown as Fn in diagram)

$$F_r = F_t \tan 25 = 3101.6 \tan 25$$

$$F_r = 1446.3\,KN$$

$$\text{Torque Transmitted (T)} = \frac{Ft}{2} \times r$$

$$= \frac{3101.6}{2} \times 635$$

$$= 984758\ KN - mm$$

Bagasse Load = 560,000 kgf (Shown as THL in diagram)
Self Weight = 40,000 kgf
Total Load = Bagasse Load+ Self Weight

= 560,000+40,000
= 600,000 kgf
= 5886 KN

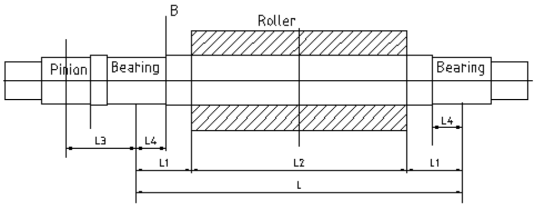


Fig 2.3 Sectional view of roller mill shaft

Bending moment calculation

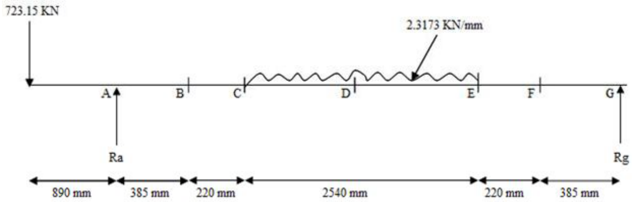


Fig 2.4 Vertical loading for determinate beam condition

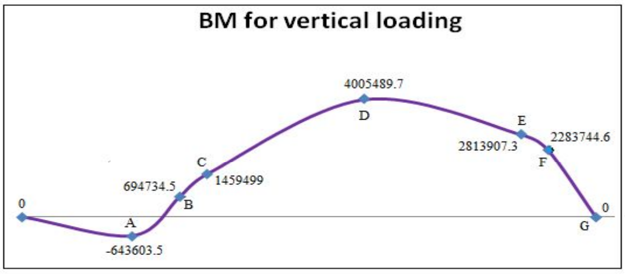


Fig 2.5 BM for vertical loading

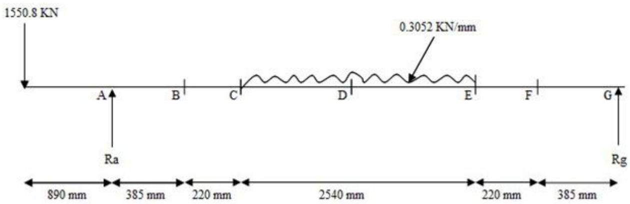


Fig 2.6 Horizontal loading for determinate beam condition

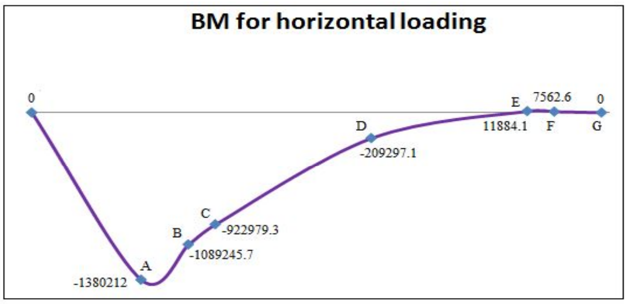
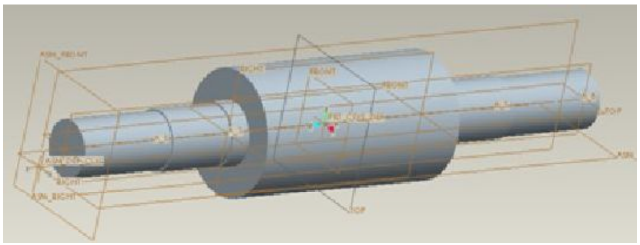


Fig 2.7 BM for Horizontal loading

III. FEA ANALYSIS

The solid shaft and hollow shaft geometry is generated in ANSYS 12 by selecting toolbox where various commands like draw, dimensioning, constraints, extrude, generate, rotate etc. are used. Then mesh is generated on the model and after that load points are defined and load values are given. Then the results are generated automatically for stress, strain and deformation in solution phase,

Assembly Model of Roll Mill Shaft:



The same shaft is used for checking effect of stress concentration in fillet and taper. Center of bearing is constrained. Combined loading is considered in comparing results. Bending moment at section B is 1222.7186 X 10^3KNmm. Calculated stress at section B is 73.2159 KN/mm2.

Fillet: fillet radius used is 20mm. a very fine mesh is used at fillet region to get accurate results

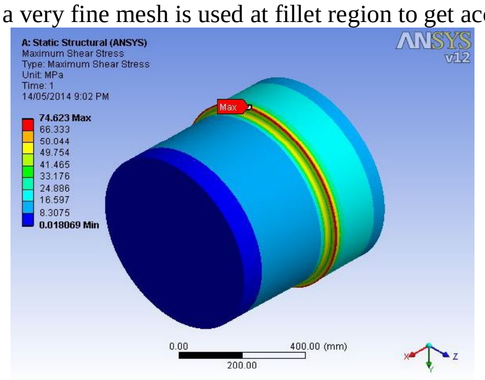


Fig 3.1 Maximum stress at section B is 74.623 Mpa.

Taper: A taper of 15 degree is used. A very fine mesh is used at taper region to get accurate results

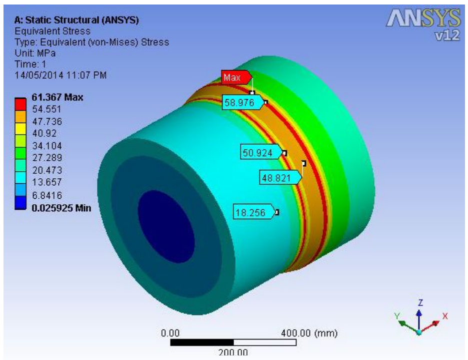


Fig 3.2 Maximum stress at section B is 61.367 Mpa.

Contact pressure between shaft and outer roller is shown in following figure. The maximum value for contact pressure on shaft surface is 64.066 N/mm2. In this case results are obtained without applying any loads in order to validate results with theoretically calculated shrink fit contact pressure.

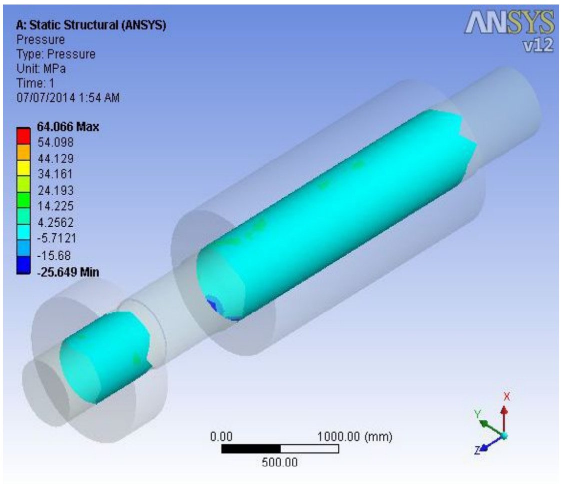


Fig 3.3 Contact pressure for solid shaft

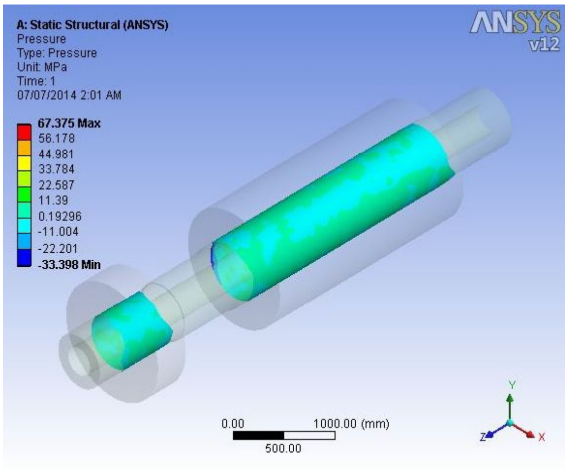


Fig 3.4 Contact pressure for hollow shaft

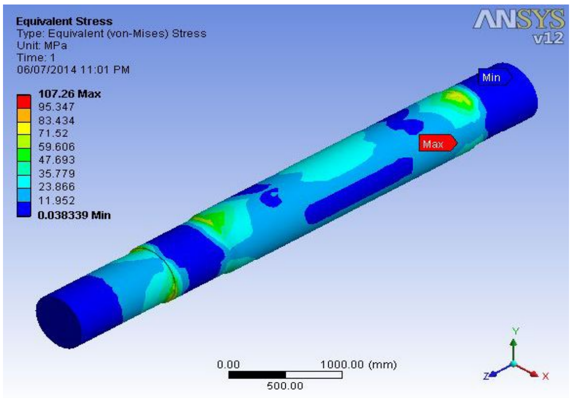


Fig 3.5 Equivalent (von-Mises) Stress for solid shaft

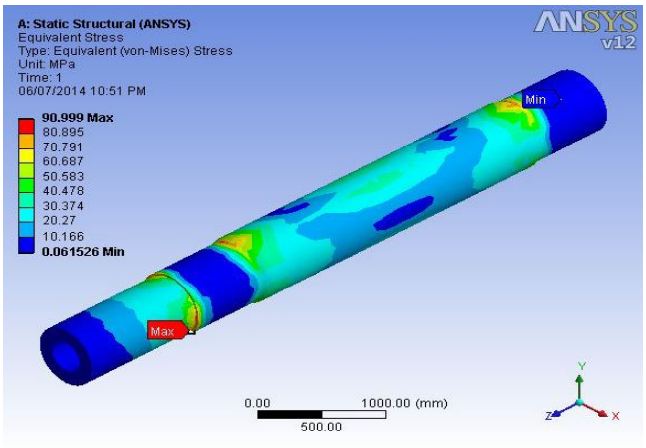


Fig 3.6 Equivalent (von-Mises) Stress for hollow shaft

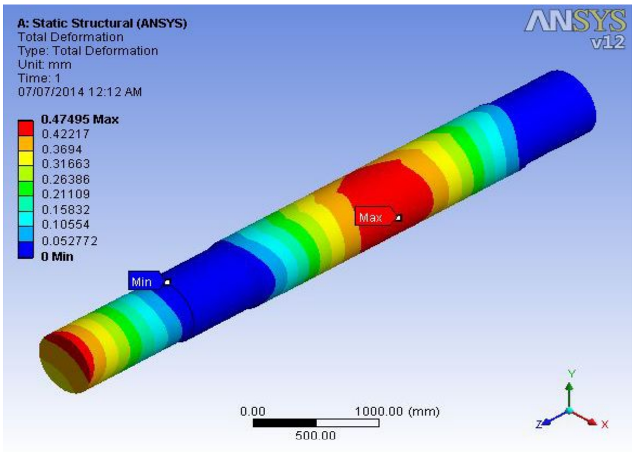


Fig 3.7 Total deformation in solid shaft

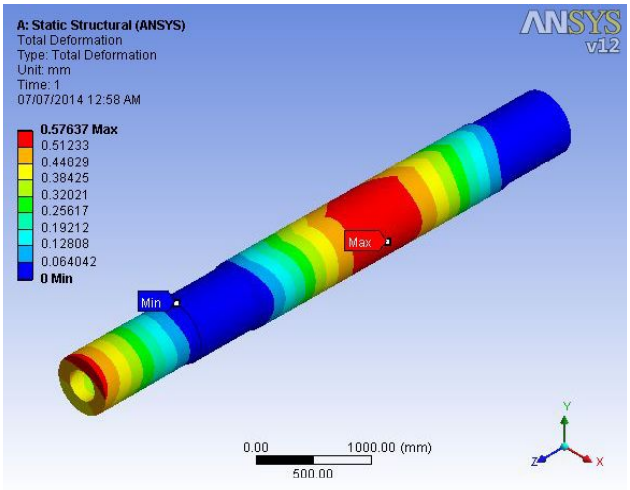


Fig 3.8 Total deformation in hollow shaft

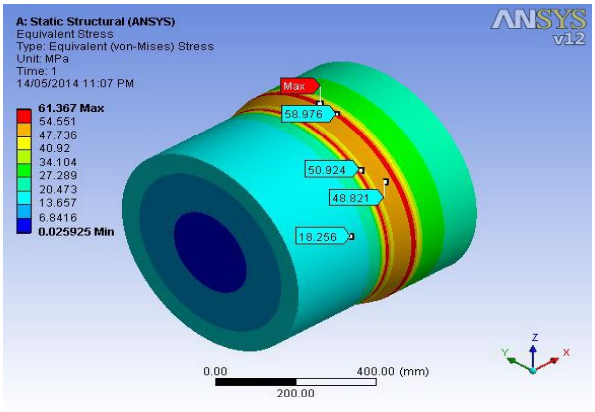


Fig 3.9 Maximum stress at section B for solid shaft

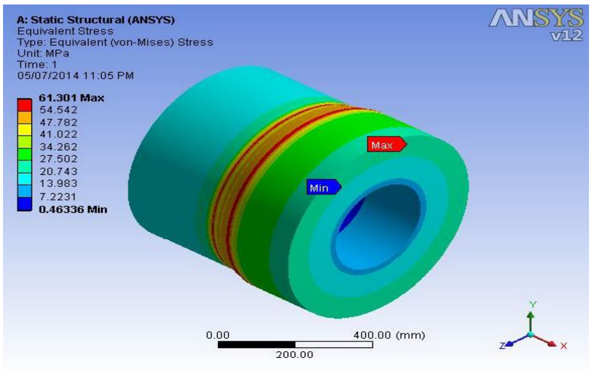


Fig 3.10 Maximum stress at section B for hollow shaft

IV. RESULTS & DISCUSSION

Roller mill shaft is analyzed theoretically as well as with the help of FEA software for its safe working by checking various parameters within limits.

Taper vs. Fillet FEA Results for stresses

- The same shaft is used for checking effect of stress concentration in fillet and taper.
- Combined loading is considered in comparing results.

Stress results for FEA analysis for solid shaft and hollow shaft.

Table1. Result table for FEA analysis stresses

Cases	Stress concentration	Calculated results	FEA results	Allowable Stress
Fillet	2	107.354	74.623	220N/mm2
Taper	1.25	60.586	61.367	220N/mm2

From above results it is obvious that stresses when Taper used is much less than the stresses when fillet is used due to its low stress concentration factor. Also the fatigue limit for taper geometry is higher than that of fillet & Stresses for taper are much less than its fatigue limit.

Contact pressure that obtained from FEA is shown in table below for hollow shaft and solid shaft

Table2 Result table for contact pressure

Contact pressure for solid shaft (N/mm2)	Contact pressure for hollow shaft (N/mm2)
64.066	67.375

Table3 Solid shaft vs. hollow shaft FEA Results

S.No.	*Solid shaft*	*Hollow shaft*
1	Material: 40c8	Material: 40c8
2	Minimum Section Modulus :1.45066e10 mm3	Minimum Section Modulus :1.35999e10 mm3
3	Ultimate tensile strength =550 MPa.	Ultimate tensile strength =550 MPa.
4	Yield strength =220 MPa.	Yield strength =220 MPa.
5	Maximum stress at section B =61.367MPa	Maximum stress at section B =61.301 MPa.
6	Equivalent (von-Mises) Stress calculated by ANSYS =107.26 MPa	Equivalent (von-Mises) Stress calculated by ANSYS = 90.999 MPa.
7	Equivalent Strain = 5.1077e-004	Equivalent Strain = 4.3333e-004
8	Total Deformation = 0.4749mm	Total Deformation = .5763mm
9	**Weight of Solid Shaft= 14087 kg**	**Weight of Hollow shaft = 10721 kg**

V. CONCLUSION

From above results and discussions it is concluded that two sugar roller mill with hollow shaft is preferable one and it offers much greater safety factors against failures.

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