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Design and Structural Analysis of Rollers in Belt Conveyor for Sugarcane Factory

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ABSTRACT

The design and optimization of material handling systems are crucial for operational efficiency in the sugarcane processing industry. Standard roller belt conveyors are frequently over-engineered, leading to unnecessary weight, high production costs, and excessive power consumption during operation. This research paper presents a detailed structural analysis and redesign of a roller belt conveyor system specifically for sugarcane factories. The methodology involves 3D modeling using Siemens NX and finite element analysis (FEA) through ANSYS Workbench to identify and address design redundancies. The research evaluates several materials, including Mild Steel (MS), ASTM A53, and Stainless steel, focusing on their structural response under varied loading conditions. Strategic geometry optimization, such as reducing thickness and refining roller dimensions, resulted in a substantial total system weight reduction of 74 kg, representing a 80.2% decrease in overall material. These findings suggest that implementing such optimized designs can lead to significant material savings and reduced energy requirements in industrial sugarcane processing.

Keywords: Weight reduction, Material Handeling, Siemens NX, ANSYS, finite element analysis, structural optimization, material saving.

1.INTRODUCTION

Material handling plays a major role in industrial operations and uses a significant share of the total power supply. A material handling system includes different equipment such as lifts, AGVs, and conveyors. Among these, conveyors are widely used in industries for continuous material movement. Conveyors are further divided into several types, including belt conveyors, roller conveyors, chain conveyors, screw conveyors, pneumatic conveyors, and roller belt conveyors. A roller conveyor is mainly used to move materials from one place to another. It is a commonly used continuous transport system because of its high efficiency, large conveying capacity, and ability to handle different materials over various distances. The high weight of conventional steel idler rollers is another concern, as a single roller can weigh more than 25 kg. This creates Occupational Health and Safety risks because rollers often need to be handled in confined or hard-to-reach areas. During maintenance or replacement, workers may suffer back or muscle injuries due to the heavy weight. Therefore, this project focuses on the design and structural analysis of a roller belt conveyor for a sugarcane factory with the objective of reducing the overall system weight. Special attention is given to critical components such as the roller. The goal is to develop a conveyor system that is safe, reliable, easy to maintain, and suitable for continuous sugarcane handling.

1.1 Problem Statement

In the complex environment of a sugarcane factory, the transport of bulk materials such as raw cane, bagasse, and sugar is a continuous and energy-intensive process. The roller belt conveyor is the primary equipment used for these tasks. However, many current industrial designs are characterized by being "heavy" and over-designed, leading to significant material wastage and high operational costs [1]. Excessive component mass in rollers increases the rotational inertia and the total static weight of the system, which in turn demands higher torque from the drive motors and increases power consumption [2]. Furthermore, the initial cost of manufacturing these over-engineered systems is high due to the volume of steel consumed. Existing studies indicate that many conveyor assemblies in the sugar industry can be optimized for weight without compromising their primary function of material transport [1], [3].

1.2 Objectives

The primary objective of this research is the design and structural optimization of a roller belt conveyor to achieve material and energy savings. Specifically, the study aims:

- To develop a detailed 3D geometric model of the conveyor assembly using Siemens NX 10.0 [2].
- To perform comprehensive static structural analysis using ANSYS Workbench (versions 15.0 and 2020 R2) to assess the performance of the system under varying payloads [3], [8].
- To explore the weight reduction potential by optimizing component thickness and geometry, specifically targeting rollers [1].
- To evaluate the structural suitability of alternative materials like Cast Iron and Titanium alloys for critical components like rollers and shafts [2], [9].
- To validate the optimized design against safety standards by calculating the factors of safety for different loading scenarios [8].

1.3. Methodology

The following are important steps for completion of objectives -

1. Check design of existing conveyor system.
2. Creating geometric model and finite element model of existing conveyor system using suitable SIEMENS NX software.
3. Analysis of critical components of system like roller by using ANSYS software.
4. Simulations for Modal Analysis.
5. Optimization of conveyor assembly for weight reduction.
6. Comparison between existing and optimized design.

2. DESIGN OF EXISTING SYSTEM OF ROLLER CONVEYOR

In the sugarcane industry, the sugar sacks are transferred from one workstation to other. The maximum load in a sugar sack is of 50 Kg. While doing the maintenance the employees may stand on the roller. Hence by considering the safety we will consider the total weight on roller as 120 Kg. So, the total load on single roller is 120 Kg. By considering all this parameters, the results are follows:

Geometric Modelling of Roller

The geometric model of the existing roller is shown in Fig 1.

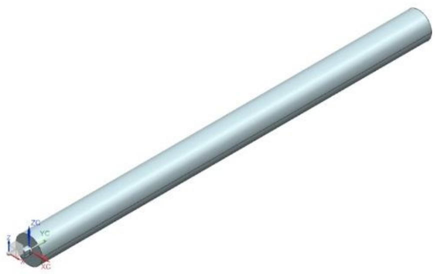

Fig 1: Geometric Modelling of existing roller.

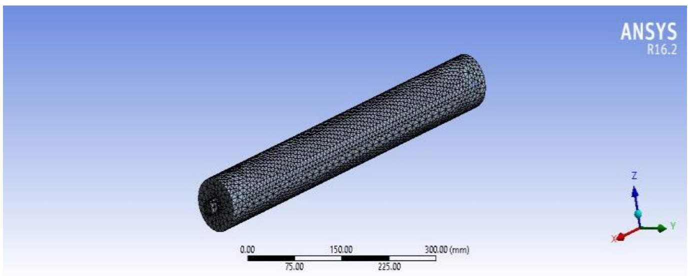

Fig 2: Meshing of existing roller.

Meshing Boundary Conditions of roller: The boundary conditions of the roller are shown in following image. The total load of 120 Kg was applied and Rollers was fixed at both ends. It is shown in Fig 3.

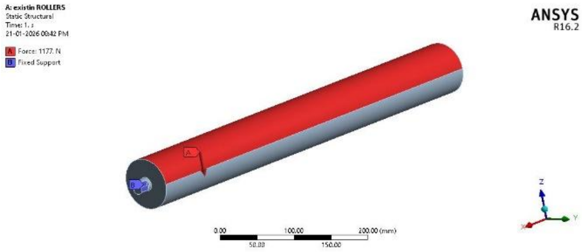

Fig 3: Boundary Conditions of existing roller.

Total Deformation of Existing roller:

After applying total load of 120 kg, uniformly distributed on roller. The deformation is shown in the following analysis results in various colour bands. The maximum deformation is shown in red band of 0.0245 mm and minimum deformation of 0 mm and shown by blue colour. It is shown in Fig 4.

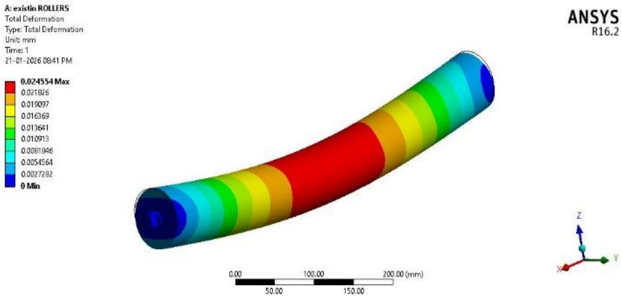

Fig 4: Total deformation of existing roller.

Stress of Existing Roller:

After applying total load of 120 kg, uniformly distributed on roller. We get analysis results for stress as shown in Fig. Maximum stress is 23.28 MPa shown by red colour and minimum stress as 0.0679 MPa and shown by blue colour. It is shown in Fig 5.

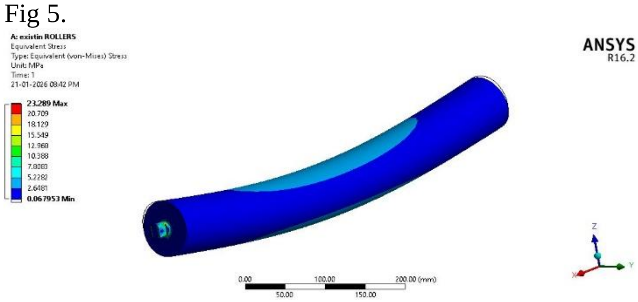

Fig 5: Equivalent Stress of existing roller.

The total weight of the rollers is 93 Kg.

3. DESIGN AND ANALYSIS OF OPTIMIZED ROLLER CONVEYOR

After study of existing system, design of that system for optimization will be started. Optimization of system will be according to one of the following cases:

1. Changing dimensions of system and keeping material same as it is.
2. Keeping same dimensions and changing material of components,
3. Changing both material as well as dimensions of component.

3.1. Design of Optimized Roller

Case 1: Changing dimensions of system and keeping material same as it is

In the sugarcane industry, the sugar sacks are transferred from one workstation to other. The maximum load in a sugar sack is of 50 Kg. While doing the maintenance the employees may stand on the roller. Hence by considering the safety we will consider the total weight on roller as 120 Kg.

Different calculations was carried out and results are as follows:

Table no. 1: Iterations carried out for roller according to case 1

Sr. No.	OD (mm)	ID (mm)	Bending Stress (MPa)	Weight (Kg)	Weight per roller (Kg)	Weight Reduction compare with existing roller (Kg)	Deformation (mm)
1	75	65	1.88	93.2	5.2	0	0.0119
2	75	67.5	2.38	71.1	4.0	22	0.0151
3	75	70	3.39	48.3	2.7	45	0.0216
4	75	72	5.43	29.3	1.6	64	0.0345
5	75	72	5.43	29.3	1.6	64	0.0345
6	72	62	2.06	89.2	5.0	4	0.0136
7	72	64	2.46	72.4	4.0	21	0.0163
8	72	66	3.15	55.1	3.1	38	0.0208
9	72	68	4.53	37.3	2.1	56	0.0299
10	72	70	8.68	18.9	1.1	74	0.0574
11	70	60	2.19	86.5	4.8	7	0.0149
12	70	62	2.62	70.3	3.9	23	0.0178
13	70	64	3.34	53.5	3.0	40	0.0227
14	70	66	4.80	36.2	2.0	57	0.0327
15	70	68	9.20	18.4	1.0	75	0.0626

Case 2) Keeping same dimensions and changing material of components

For case 2, we have studied the ASTM A53 & Stainless Steel materials. We have performed the calculations and results are as follows:

The summary of the above calculations is shown in table 7.2:

Table 2: Iterations for case II for Optimised roller

Material	OD (mm)	ID (mm)	Bending Stress (MPa)	Weight (Kg)	Weight per roller (Kg)	Weight Reduction compare with existing roller (Kg)	Deformation (mm)
ASTM A53	75	65	1.88	83.1	4.6	10	0.0119
Stainless Steel ASTM A554	75	65	1.88	95	5.3	-2	0.0119

Case 3) - Changing both material as well as dimensions of component

In this case we will change both materials and dimensions of the existing rollers. The iterations are carried out as following.

Table no. 3: Iterations carried out for roller according to case 2

Sr. No.	Material	OD (mm)	ID (mm)	Bending Stress (MPa)	Weight (Kg)	Weight per roller (Kg)	Weight Reduction compare with existing roller (Kg)	Deformation (mm)
1	ASTM A53	75	65	1.88	83.1	4.6	10	0.0119
2		75	67.5	2.38	63.4	3.5	30	0.0151
3		75	70	3.39	43.0	2.4	50	0.0216
4		75	72	5.43	26.2	1.5	67	0.0345
5		75	72	5.43	26.2	1.5	67	0.0345
6		72	62	2.06	79.5	4.4	14	0.0136
7		72	64	2.46	64.6	3.6	29	0.0163
8		72	66	3.15	49.1	2.7	44	0.0208
9		72	68	4.53	33.2	1.8	60	0.0299
10		72	70	8.68	16.9	0.9	76	0.0574
11		70	60	2.19	77.1	4.3	16	0.0149
12		70	62	2.62	62.7	3.5	31	0.0178
13		70	64	3.34	47.7	2.7	45	0.0227
14		70	66	4.80	32.3	1.8	61	0.0327
15		70	68	9.20	16.4	0.9	77	0.0626
16	Stainless	75	65	1.88	95.0	5.3	-2	0.0119

17	Steel ASTM A554	75	67.5	2.38	72.5	4.0	21	0.0151
18		75	70	3.39	49.2	2.7	44	0.0216
19		75	72	5.43	29.9	1.7	63	0.0345
20		75	72	5.43	29.9	1.7	63	0.0345
21		72	62	2.06	90.9	5.0	2	0.0136
22		72	64	2.46	73.8	4.1	19	0.0163
23		72	66	3.15	56.2	3.1	37	0.0208
24		72	68	4.53	38.0	2.1	55	0.0299
25		72	70	8.68	19.3	1.1	74	0.0574
26		70	60	2.19	88.2	4.9	5	0.0149
27		70	62	2.62	71.6	4.0	22	0.0178
28		70	64	3.34	54.5	3.0	39	0.0227
29		70	66	4.80	36.9	2.0	56	0.0327
30		70	68	9.20	18.7	1.0	74	0.0626

Thus, after studying all three cases, following roller specification was selected as optimized roller.
OD = 70 mm, ID = 68 mm, Material = Mild steel
The total weight is 18.4 Kg. Thus, further study of selected best solution is as follow.

Geometric modelling of optimized roller

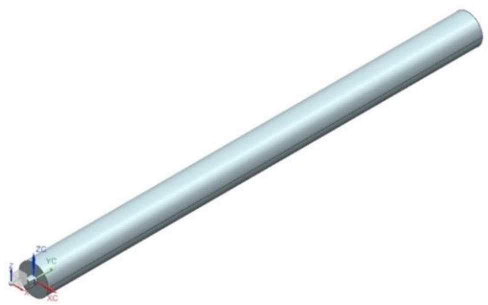

Fig 6: Geometric modelling of optimised roller

Meshing of Optimised roller:

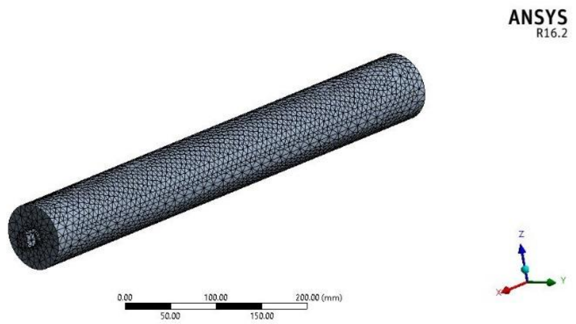

Fig 7: Meshing of optimised roller

Boundary Conditions of Optimized roller:

The boundary conditions of the roller are shown in following image. The total load of 120 Kg was applied and Rollers was fixed at both ends. It is shown in Fig 8

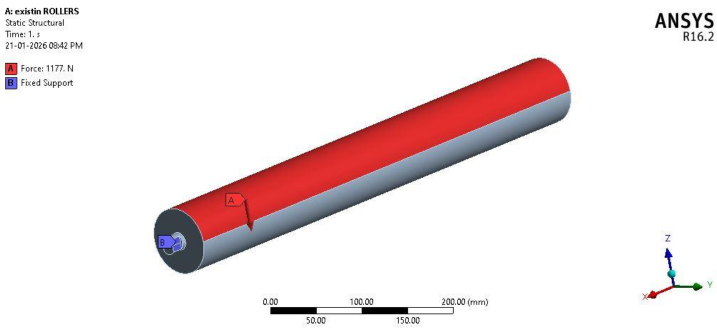

Fig 8: Boundary Conditions of optimised roller.

Total Deformation of Optimised roller:
After applying total load of 120 kg, uniformly distributed on roller. The deformation is shown in the following analysis results in various color bands. The maximum deformation is shown in red band of 0.135 mm and minimum deformation of 0 mm and shown by blue color. It is shown in Fig 9

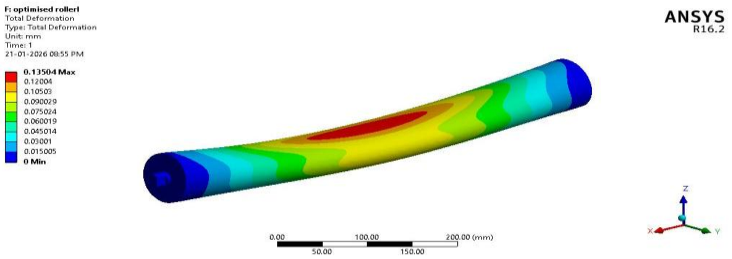

Fig 9: Total deformation of optimised roller

Stress of optimized Roller:
After applying total load of 120 kg, uniformly distributed on roller. Maximum stress is 49.73 MPa shown by red colour and minimum stress as 0.28 MPa and shown by blue colour. It is shown in Fig 10

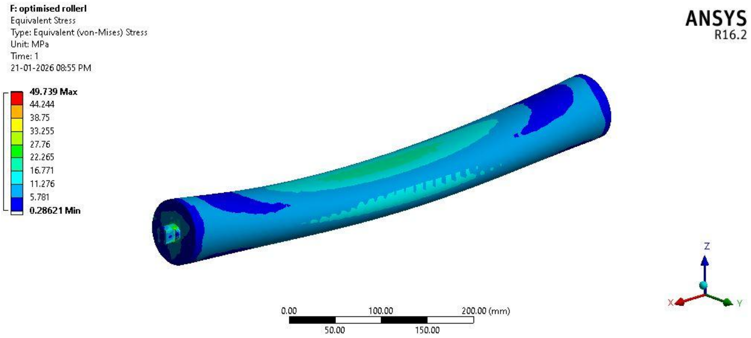

Fig 10: Equivalent stress of optimised roller

4.RESULTS AND DISCUSSION

The analysis of the existing conveyor revealed that it was under-stressed, confirming the potential for weight reduction. For the Mild Steel roller, the maximum bending stress was only 1.88 MPa, while the allowable stress was 196.67 MPa. For optimizing roller above iterations was carried out. By considering all three cases iterations was carried out and one best solution was selected.
Roller with ID = 68 mm, OD = 70 mm was selected as optimized roller with deformation 0.0626 mm.

Comparison of existing and optimized system

Table no. 43: Comparison of existing and optimized system

Sr. No.	Component	Weight of Existing System (Kg)	Weight of Optimized system (Kg)	Weight reduction (Kg)
1	Roller	93	18.4	74.6

The existing system is Optimised in this project. The summary of optimisation is shown in above table. The weight of existing system is 93 Kg and weight of Optimised system is 18.4 Kg. Thus, we achieved 74.6 Kg of weight reduction.

Material Saving due to optimization
Material saving through optimization is important for improving the design and efficiency of roller conveyors in the sugarcane industry. By analyzing load conditions, stress distribution, and functional requirements, we have reduced the material used in the roller system without affecting its strength or performance. This not only makes the conveyor lighter but also lowers costs, saves energy, and supports environmental sustainability. The table 9.4 shows the material saving after optimisation.

Table no. 5: Material Saving due to optimization

Sr. No.	Component	Weight of Existing System	Weight of Optimized system (Kg)	Weight reduction (Kg)	Material usage compare to	Material saved (%)

		(Kg)			**existing (%)**	
1	Roller	93	18.4	74.6	19.8	80.2

Thus, material saving in optimised system is 80.2 % than that of existing system. Thus, there is also cost saving in material due to optimization.

5. CONCLUSION

The design and analysis of the roller conveyor in the sugarcane industry showed great improvements through optimization. The existing roller, which was heavy, has been redesigned to fix its drawbacks. The optimized system is lighter and more efficient.

1. By changing the shape and materials of rollers, significant material savings were achieved. The rollers were made 74.6 Kg lighter, saving 80.2% of the material.
2. Overall, the optimized design of rollers reduced the total weight by 74.6 kg. The weight reduction did not affect the system's ability to carry loads. These improvements also reduced the cost of the system and saved power, making it more sustainable and efficient.
3. This study shows how optimization can improve roller conveyor systems and highlights its potential use in other areas of the sugarcane industry.

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