Weight Optimization Of Support Roller By Using Theoretical, Finite Element And Experimental Analysis

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Abstract: An appropriate design of Support roller is significant for satisfactory performance of conveyor system. A number of Support rollers and return rollers are used in conveyor system so that the excess weight of the Support roller affects the total weight of system and also enhances the power consumption. Excess material used in conveyor system does not add any values in the performance on the contrary it reduces energy efficiency and increases manufacturing cost. It is notable to decrease power consumption and manufacturing cost of material handling sector. So that, in this paper we intended to reduce weight of Support roller to increase energy efficiency of conveyor system with reduction in material cost by weight optimization of roller.

Index Terms: Finite Element Analysis, Universal Testing Machine, Support rollers, Weight reduction, Belt conveyor, Material Handling, ANSYS, SolidWorks, Optimization.

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Material handling is one of the most principle department among all departments in any industry. This is an advanced technology used to reduce lead time in production. Material handling system consume a considerable proportion of the total power supply in industry. This system contains various machines like Lifts, AGV's, Conveyors, etc. from which conveyors are mostly used in industries because of its reliability and durability. Conveyors are used in industries for automated circulation of components. Conveyor is material handling device which continuously transfer material from point to point over a definite period of time. Conveyors are further classified in various types such as belt conveyor, pneumatic conveyor, roller belt conveyor and bucket conveyor etc. From all above types of conveyor systems most of the industries prefer belt conveyors for material handling because of its noiseless operations and long life. Belt conveyor consists base frame, drive pulley, driven pulley, snub pulley, drive unit, return rollers and Support rollers. The Support roller is vital part of belt conveyor system, it bears total weight of a sand, absorbs shock, retain belt alignment and keep tension in the belt. As a conveyor is principle equipment in material handling system, weight optimization of conveyor become essential for increase power efficiency and decrease manufacturing cost of total material handling system. So, in this research study we will focus on weight reduction of primary component of a conveyor that is Support roller which contributes 15% to 20% in a total weight of conveyor belt. Some of the literature studies on the related topics are as follows:

Amol Kharage et al. [1] carried out analysis of existing gravity roller conveyor and optimize its important component by replacing mild steel with carbon fiber for weight reduction. The geometrical model is developed in Pro/E Wildfire 5 and performed finite element analysis in ANSYS software. The results of transient, static and modal analysis of optimized and existing models are compared.

Tabello Mathaba et al. [2] derived generic energy model for the long belt conveyor based on belt resistance. They used twain variables which are power equation and partial differential equation for the belt to measure the transported bulk material. The mathematical model derived by author gives 4% more accuracy results than existing mathematical model. Shirong Zhang et al. [3] focused on the energy saving of belt conveyor system by increasing operational efficiency. In this research paper author has reviewed an existing energy model and then proposed an analytical model which is depends on some coefficients. These coefficients can derive from field experiments or by design parameters. This derived model guarantees an improved accuracyMiroslav Bajda et al. [4] proposed an experimental test setup and procedure to identify main components of belt conveyor movement resistant. The main aim of this test is to state constructional feature of conveyor that develops low rolling resistance on idler and bending resistance on pulleys. The results of testing compared for two belts on the basis of generated movement resistance on the belt conveyor. Yogesh Padwal et al. [5] designed a 30 m distance belt conveyor for material handling of semi-finished material to replace fork lift machine. For that author has designed a geometrical model in Catia and validation of model is done by using Nastran. In this paper author has separately design components of conveyors and tested for external forces that have applied in assembly environment. Rohini Sangolkar et al. [6] carried out static structural analysis of industrial belt conveyor system by using ANSYS. The geometrical model for analysis is developed in Creo parametric. All steps of finite element analysis are described in this research study. Maximum deformation and von-misses stress are calculated from analysis for applied load of 10KN. Nylon 66 and ASTM A36 hot rolled steel is used for belt and structure respectively for analysis. It is noted that from all above study that much less work has done on the belt conveyor system. So that, there is scope to increase energy efficiency by optimizing weight of crucial components of belt conveyor. In this research work we intended to optimize weight of the Support roller for that first we calculate factor of safety for existing design and then calculate maximum bending stress and maximum deformation on this model by using ANSYS. After that we design a Support roller for optimized weight considering factor of safety, maximum bending stress and maximum deformation and validate optimized design by

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finite element and experimental analysis for best fitted specifications

2 PROBLEM DEFINITION

The existing design of belt conveyor is heavy weight which unknowingly increases cost, increases power consumption and causes difficulty in maintenance. To demolish these problems, we are going to redesign existing system with the help of analysis and optimization.

2.1 Objectives of Paper

1. Study and analyze existing design of Support roller to check scope for weight optimization.
2. Modify dimensions and material of existing Support roller for weight optimization.
3. The optimization of the Support roller is going through following cases:
   A. Changing roller dimensions, and retaining the same material as it is.
   B. By keeping same geometrical dimensions and Modifying material of components.
   C. Changing both material and Part dimensions.
4. Validate redesigned model by finite element analysis and universal machine testing.

3 ANALYSIS OF EXISTING ROLLER

In this work for designing of Support roller, we use the SolidWorks and for analysis ANSYS 15.0 software is used. The material selected Support roller is mild steel corresponding properties are given in Table 1.

TABLE 1

PROPERTIES OF MILD STEEL

Property	Value
Density (Kg/m3)	7860
Young's Modulus (MPa)	2.10×10^5
Yield Strength (MPa)	370
Ultimate Tensile Strength (MPa)	590
Poisson's Ratio	0.3

3.1 Modelling of Existing Support Roller

Support roller is significant component in the conveyor belt system and the performance of the conveyor depends on strength and dimensions of the roller. Roller carries maximum amount of load, so that we focused on analysis to enhance the performance and reduce power consumption with weight optimization. Initially CAD model of Support roller was developed in SolidWorks 2019. Fig. 1 shows the CAD model of the roller.

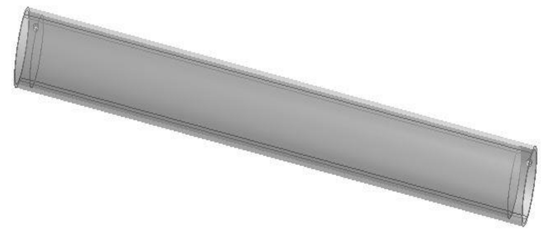

***Fig. 1**. CAD model of Support Roller*

3.2Theorotical Analysis of existing Support Roller

We have done theoretical calculations of existing Support roller to determine bending stress, deflection, weight and factor of safety. The stresses developed in the roller are due to sand weight. The weight of sand per meter is 200 Kg is uniformly distributed on both the roller. The distance between two rollers is 1 meter. The weight of sand on each roller is 100 Kg but for design calculation we consider extreme loading condition that is 200Kg load per roller. Analytical Calculations was carried out as follows

Max Bending Stress,

$$\sigma_b = \frac{M_{max} \times Y}{I} \quad (1)$$

= 6.68 MPa

Where,

M_{max}= Maximum Moment = 113.4036 Nm

I =Moment of Inertia = 7.6741×10-7m4

Y = Distance from neutral axis =38 mm

Deflection,

$$Y_{max} = \frac{5wL^3}{384 \times E \times I} \quad (2)$$

= 0.0575 mm

Where,

w= Weight of sand

L= Length of roller

E= Modulus of Elasticity

Total weight of rollers in system,

$$W = V \times \rho \times N \quad (3)$$

= 83.20 Kg

Where,

V= Volume of Roller

ρ= Density of mild steel

N= Number of rollers

Factor of Safety,

$$FOS = \frac{\sigma_{all}}{\sigma_b} \quad (4)$$

= 29.5

Where,

σ_{all}= Allowable stress

σ_b= Maximum bending stress

From above calculations our design is safe because F.O.S. is greater than 1.5. So, design is safe and suitable for optimization.

3.3 FEA of Existing Support Roller

Static structural analysis used to calculate forces, strain, displacement and stresses developed in the component due to applied loads and boundary conditions. For static analysis we used ANSYS Software. Basically, finite element analysis consist of three steps as follows,

Pre-processing consists of importing geometry in .igs or .step file format. After importing the geometry meshing has done. Purpose of meshing is discretizing whole geometry into small number of elements and automatic mesh generation method is used. Next step is applying the boundary conditions.

Processing solves the equation background of computer processor.
Post processing gives the desired results such as total deformation, stress and strains.

The FEA results are given below,

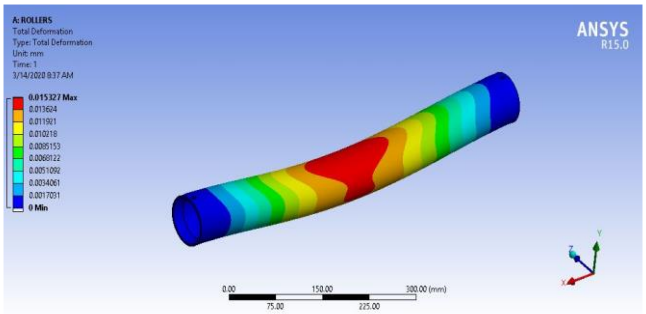

Fig. 2. *Total Deformation of Existing Roller*

Fig. 2. shows total deformation of existing roller for a given load of 200kg. The maximum deformation is 0.015327 mm.

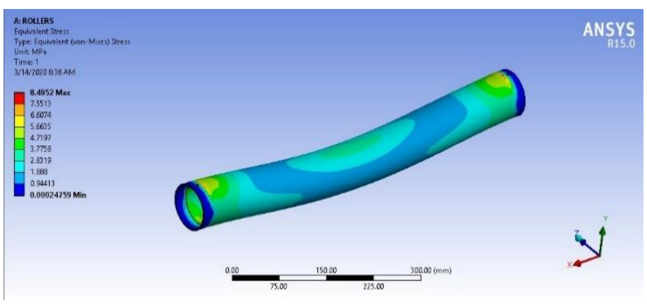

Fig. 3*. Equivalent Stress in Existing Roller.*

Fig. 3. shows von-mises stress on existing roller for a given load of 200kg. The maximum stress is 8.4952 MPa.
Above results shows that value of analytical and FEA results are approximately same.

4 DESIGN FOR OPTIMIZED SYSTEM

From above calculations and analysis, we know that, the weight of the Support roller is excess. So, that we required to optimize weight of Support roller, by changing the dimensions, by changing material and by changing both and from results we choose the well-suited dimension and material. All the values of bending stress, deformation, weight and FOS are calculated by using equations (1) to (4) given above.

4.1 Changing dimensions of system

In this case we are changing dimensions of Support roller which are internal and external diameters and calculating bending stress, FOS, weight, weight optimization and deformation for each of them.

TABLE 2
ANALYTICAL CALCULATION RESULTS OF ROLLER FOR DIFFERENT DIMENSIONS

Sr. No.	OD (mm)	ID (mm)	Bending Stress (Mpa)	Factor of Safety	Weight (Kg)	Deformation (mm)
1	60	55	16.62	11.8	41.5	0.178
2	60	58	38.53	5.10	17.0	0.414
3	60	59	75.16	2.62	8.6	0.807
4	76.1	74.1	23.70	8.30	21.7	0.200
5	76.1	72	12.05	16.3	43.9	0.102
6	76.1	70.5	9.09	21.6	59.3	0.077
7	89	84.5	7.99	24.6	56.4	0.057
8	89	82.5	5.72	34.3	80.5	0.041

4.2 Keeping same dimensions and changing material of components

In this case we are changing material of component without changing dimensions and calculating bending stress, FOS, weight, weight optimization and deformation for each of them.

TABLE 3
ANALYTICAL CALCULATION RESULTS OF ROLLER FOR DIFFERENT MATERIALS

Sr. No.	Material	OD (mm)	ID (mm)	Bending Stress (Mpa)	FOS	Weight (Kg)	Deformation (mm)
1	ASTM A554	76	68	6.695	25	87	0.061
2	IS 4923				22	84.36	0.056

4.3 Changing both material as well as dimensions of component

In this case we are changing both dimensions and material of Support roller and calculating bending stress, weight, weight optimization and deformation for each of them. In this case, IS 4923 and Stainless-Steel ASTM A554 are used.

TABLE 4
ANALYTICAL CALCULATION RESULTS OF ROLLER FOR DIFFERENT DIMENSIONS AND MATERIALS

Sr. No.	Material	OD (mm)	ID (mm)	Bending Stress (Mpa)	Weight (Kg)	Deformation (mm)
1	Stainless Steel ASTM A554	60	55	16.62	43.3	0.192412
2		60	58	38.53	17.8	0.445980
3		60	59	75.16	9.0	0.869850
4		76.1	74.1	23.70	22.6	0.216272
5		76.1	72	12.05	45.8	0.109985
6		76.1	70.5	9.09	61.9	0.082965
7		89	84.5	7.99	58.8	0.062332
8		89	82.5	5.72	84.0	0.044646
9	IS 4923	60	55	16.62	42.1	0.187602
10		60	58	38.53	17.3	0.434831
11		60	59	75.16	8.7	0.848104
12		76.1	74.1	23.70	22.0	0.210865
13		76.1	72	12.05	44.5	0.107236
14		76.1	70.5	9.09	60.1	0.080891
15		89	84.5	7.99	57.2	0.060774
16		89	82.5	5.72	81.6	0.040256

From above cases, we choose Support roller on the basis of weight reduction, total deformation and FOS. The specifications of this Support rollers are as follows,
OD = 76.1 mm
ID = 74.1 mm
Material = Mild steel

4.4. Finite element analysis of Optimized Support roller
We design a CAD model of optimized specifications found from theoretical calculations and this CAD model is prepared in SolidWorks. For validation of theoretical results, we done FEA and experimental analysis of roller of optimizes dimensions.

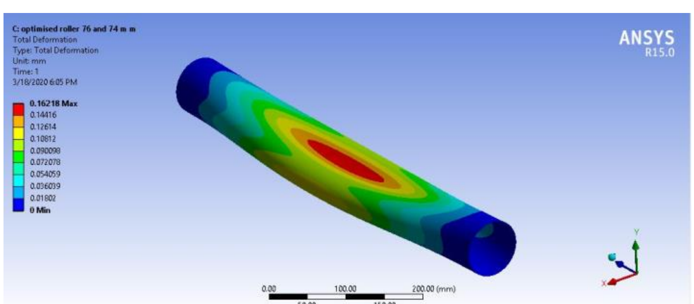

***Fig. 4**. Total Deformation of Optimized Roller*

Fig. 4 shows total deformation of optimized roller for a given load of 200kg. The maximum deformation is 0.16218 mm.

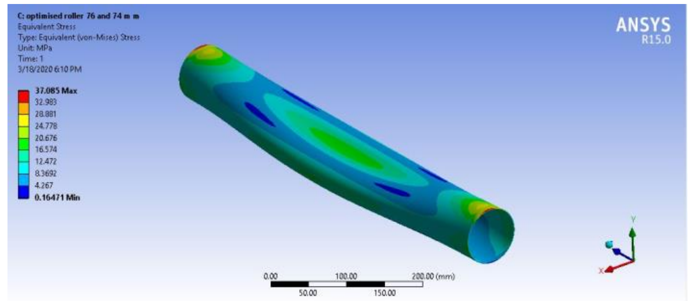

***Fig. 5**. Equivalent Stresses in Optimized Roller*

Fig. 5 shows von- mises stress of optimized roller for a given load of 200kg. The maximum von- mises stress is 37.085MPa.

5 EXPERIMENTAL WORK

Experimental work of Support roller is done by using Universal testing machine. The fig. 5 shows experimental setup. The purpose of experimentation is to know the actual deformation and compressive strength of optimized roller. The value of deformation is 0.2028 mm and compressive strength is 45 MPa. We also know that under simple uniaxial compression applied stress is equal to von-misses stress. Hence, it is validated that selected specifications of Support roller are well suited for manufacturing as well as for operational use.

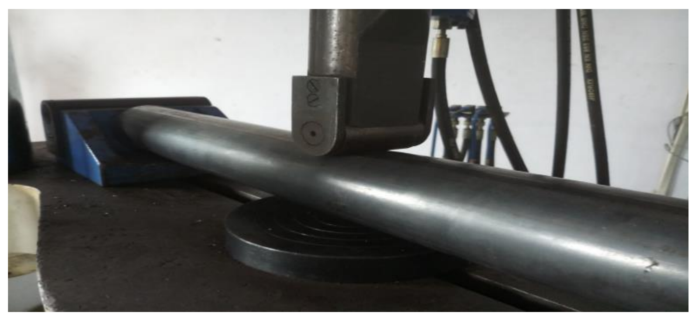

***Fig. 5.** Experimental Setup.*

6 CONCLUSIONS

The purpose of this research paper is developing a specification for the Support roller to optimize the weight and reduce power consumption. For modeling and analysis of a Support roller SolidWorks and ANSYS software's are used respectively. From theoretical calculations we get optimized dimensions of roller. FEA and experimental analysis is used to validate the optimized roller specifications. The results of theoretical, FEA and experimental analysis are approximately same and both stress and deformation are in limit. Hence this design is safe for manufacturing. The total weight reduction of Support roller is from 84 Kg to 21.7 Kg. We have saved 62.3 kilograms per Support roller and total weight reduction in system is 1246 kilograms. Total weight optimization of Support roller is 35%.

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