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Analysis and Optimization of A Roller Conveyor System by using Ceramic Materials

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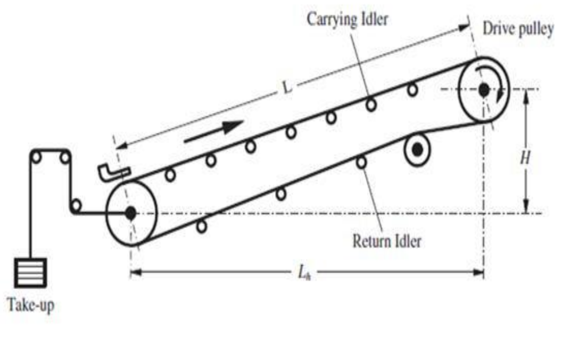
ABSTRACT

A conveyor system is a common piece of mechanical handling equipment that moves materials from one location to another. Conveyors are especially useful in applications involving the transportation of heavy or bulky materials. Conveyor systems allow quick and efficient transportation for a wide variety of materials, which make them very popular in the material handling and packaging industries. The objectives of the project are to model the conveyor system to perform structural analysis to optimize parameters critical parts of roller conveyor system like Roller, chassis and support, to minimize the overall weight of assembly and material of the roller conveyor system, and compare the results with the existing system. The geometrical modeling is to done in Pro/E and Analysis is to done by using Ansys.

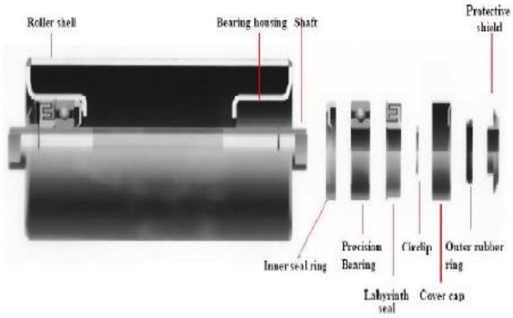
Keywords: Roller Conveyor System, Ceramic Materials, VSD, Health and Safety, CAD/CAM /CAE software, Parametric Technology Corporation

I. INTRODUCTION

Material handling is an important sector of industry, which is consuming a considerable proportion of the total power supply. For instance, material handling contributes about 10% of the total maximum demand in South Africa. Belt conveyors are being employed to form the most important parts of material handling systems because of their high efficiency of transportation. It is significant to reduce the energy consumption or energy cost of material handling sector. This task accordingly depends on the improvement of the energy efficiency of belt conveyors, for they are the main energy consuming components of material handling systems.



Principle working of belt conveyor



Parts of roller.

Consequently, energy efficiency becomes one of the development focuses of the belt conveyor technology. A belt conveyor is a typical energy conversion system from electrical energy to mechanical energy. Its energy efficiency can generally be improved at four levels: performance, operation, equipment, and technology. However, the Majority of the technical literature concerning the energy efficiency of belt conveyors focuses on the operational level and the equipment level. In practice, the improvement of equipment efficiency of belt conveyors is achieved mainly by introducing highly efficient equipment. The idler, belt and drive system are the main targets. In the influences on idlers from design, assembly, lubrication, bearing seals, and maintenance are reviewed. Energy saving idlers is proposed and tested in Energy optimized belts are developed in by improving the structure and rubber compounds of the belts. Energy-efficient motors and variable speed drives (VSDs) are recommended in general, extra investment is needed for the equipment retrofitting or replacement; and the efficiency improvement opportunities are limited to certain equipment. Operation is another aspect for energy efficiency of belt conveyors.

A conveyor system is a common piece of mechanical handling equipment that moves materials from one location to another. Conveyors are especially useful in applications involving the transportation of heavy or bulky materials. Conveyor systems allow quick and efficient transportation for a wide variety of materials, which make them very popular in the material handling and packaging industries. Many kinds of conveying systems are available, and are used according to the various needs of different industries. There are chain conveyors (floor and overhead) as well. Chain conveyors consist of enclosed tracks, I-Beam, towline, power & free, and hand pushed trolleys. Conveyor systems are used widespread across a range of industries due to the numerous benefits they provide. Conveyors are able to safely transport materials from one level to another, which when done by human labor would be strenuous and expensive.

They can be installed almost anywhere, and are much safer than using a forklift or other machine to move materials. They can move loads of all shapes, sizes and weights. Also, many have advanced safety features that help prevent accidents. Conveyors can be located in areas that cause significant problems with excessive noise production. An example of this is the location of conveyors in some coal export terminals in Australia, which are located across a bay from residential areas. The coal loading conveyors can produce noise levels that become an annoyance, especially at night time when the ambient noise levels are low. For these reasons decreasing the noise produced by conveyors is an important topic, and producing an idler roller that lowers the noise emission from the conveyor belt assemblies will have significant benefits to both the workers in the factories and the community as a whole. The weight of traditional steel idler rollers can also be a problem, particularly for wide belts which can have an individual roller weigh in excess of 20kg.

This presents an Occupational Health and Safety (OH&S) risk, as the rollers often need to be maneuvered into hard to reach positions, or places with limited access. The maintenance or replacement of these idler rollers has the potential to injure the worker conducting such maintenance through back and muscle strains. In addition to the potential OH&S problems that may be caused by heavy rollers, the weight can also become an issue when a large number of idlers need to be replaced. The number of rollers in a conveyor is often in the hundreds, however, can go up to thousands depending on the length of the conveyor. Because the steel idler rollers are heavy, only one roller may be carried at a time due to their weight. If the conveyor is elevated, and only accessible via a walkway, such a task could require many trips to be made to in order to replace the idlers. A light weight idler would make it possible to carry two idlers at a time, thus greatly reducing the workload. A detailed search of the available literature was conducted to determine any known causes for excessive noise production from conveyors. The search showed a limited amount of information existed dealing with noise production of roller conveyors, which are typically found in packaging and sorting warehouses. However, in the case of belt conveyors, the work in the area of noise production was sparse. The material found for roller conveyors was often relevant to belt conveyors, and this information was used in conjunction with previous studies conducted by Tyton Conveyors to determine the main sources of noise in belt conveyors.

Failure to include transient response to elasticity can result in inaccurate prediction of:

- ✓ Maximum belt stresses
- ✓ Maximum forces on pulleys
- ✓ Minimum belt stresses and material spillage
- ✓ Take-up force requirements
- ✓ Take-up travel and speed requirements
- ✓ Drive slip
- ✓ Breakaway torque
- ✓ Holdback torque
- ✓ Load sharing between multiple drives
- ✓ Material stability on an incline

It is, therefore, important a mathematical model of the belt conveyor that takes belt elasticity into account during stopping and starting be considered in these critical, long applications.

COMPOSITE MATERIALS

A composite material is usually made up of at least two materials out of which one is the binding material, also called matrix and the other is the reinforcement material. By definition, composite materials consist of two or more constituents with physically separable phases. Composites are materials that comprise strong load carrying material (known as reinforcement) imbedded in weaker material (known as matrix). Reinforcement provides strength and rigidity, helping to support structural load. The matrix or binder maintains the position and orientation of the reinforcement. Significantly, constituents of the composites retain their individual, physical and chemical properties yet together they produce a combination of qualities which individual constituents would be incapable of producing alone. The reinforcement may be platelets, particles or fibres and are usually added to improve mechanical properties such as stiffness, strength and toughness of the matrix material.

II. METHODOLOGY

OBJECTIVES:

1. Check design of existing conveyor system.
2. ANSYS applied for linear static and optimization analysis.
3. Simulations for linear static Analysis.
4. Optimization of conveyor assembly for weight reduction.
5. Comparison between existing and optimized design.

PROBLEM DEFINITION:

The existing High carbon steel roller conveyor system is not satisfactory for the material optimization. Due to the disadvantages of high carbon steel having poor strength, No strain resistance, Very poor in heat conductor, more weight. So the existing system is replaced by composite materials.

PROPOSED SOLUTION:

The High carbon steel roller conveyor system is to be replaced by composite materials for the material optimization with optimal performance. Due to the advantages of composite materials having Light weight, High strength, Corrosion resistance, High impact strength, Non-conductive, High fatigue resistance, high ultimate strain. The analysis is to be conducted to verify the best material for the assembly of roller conveyor system.

1. Check design of existing conveyor system.
2. Simulation method applied to optimize parameters of conveyor assembly.
3. Simulations for linear static Analysis.
4. Optimization of conveyor assembly for weight reduction.
5. Comparison between existing and optimized design.

STATIC STRUCTURAL ANALYSIS:

A static analysis calculates the effect of steady loading condition on a structure, while ignoring inertia and damping effects, such as those caused by time varying loads. A static analysis can, however, include steady inertia load (such as gravity and rotational). Design and analysis of roller conveyor for weight optimization and material saving (velocity) and time varying load that can be approximated as static equivalent loads (such as static equivalent wind and seismic loads commonly defined in many building codes). Select element and apply material properties. Static analysis determines the displacements, stresses, strains, and forces in structures or components caused by lodes that do not induce significant inertia and damping effects. Steady loading and response conditions are assumed; that is, the loads and the structure's response are assumed to vary slowly with respect to time.

Loads in a Static Analysis:

Static analysis is used to determine the displacements, stresses, strains, and forces in structures or components caused by loads that do not induce significant inertia and damping effects. Steady loading and response conditions are assumed; that is, the loads and the structure's response are assumed to vary slowly with respect to time. The kinds of loading that can be applied in a static analysis include:

- ✓ Externally applied forces and pressures
- ✓ Steady-state inertial forces (such as gravity or rotational velocity)
- ✓ Imposed (non-zero) displacements
- ✓ Temperatures (for thermal strain)
- ✓ Fluences (for nuclear swelling)

III. MODELLING AND ANALYSIS

Pro/E:

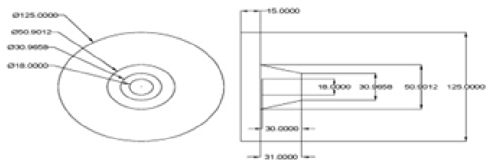
PTC Creo formerly known as PRO/ENGINEER is a parametric, integrated 3D CAD/CAM/CAE solution created by Parametric Technology Corporation (PTC). It is the world's leading CAD/CAM /CAE software, gives a broad range of integrated solutions to cover all aspects of product design and manufacturing. It was the first to market with parametric, feature-based, associative solid modeling software. The application runs on Microsoft windows platform, and provides solid modeling, assembly modeling and drafting, finite element analysis, direct and parametric modeling and NC and tooling functionality for mechanical engineers.

Modeling of roller conveyor system is done in Pro/E which is as follows:

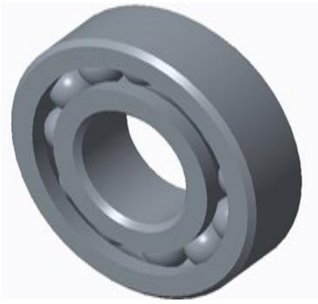
Axial rod-2D

Axial rod-3D

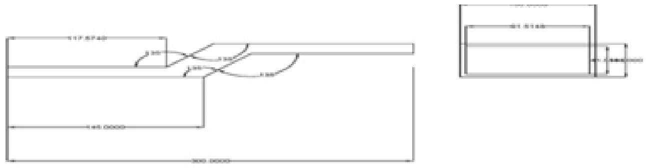
Bearing-2D



Assembly of bearing-3D



Leg supporter-2D



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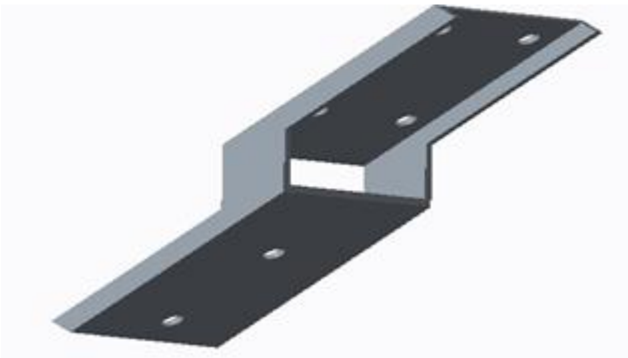
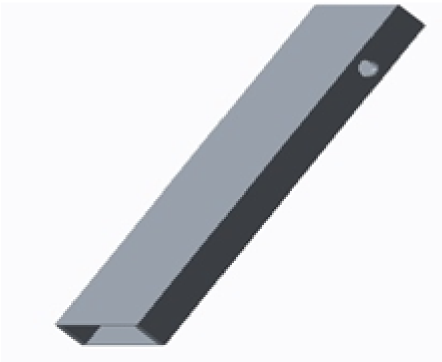
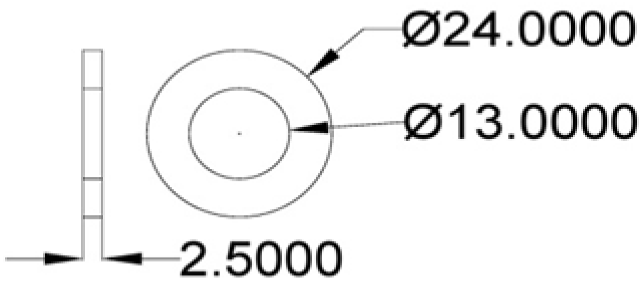


Leg-2D

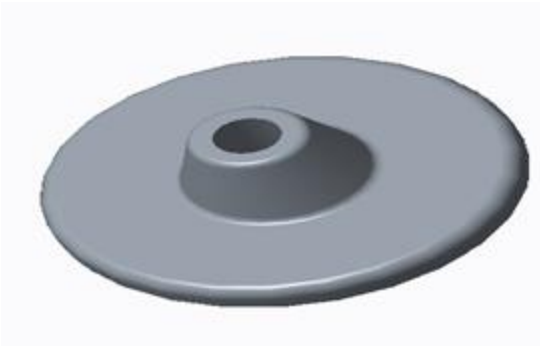
Leg-3D



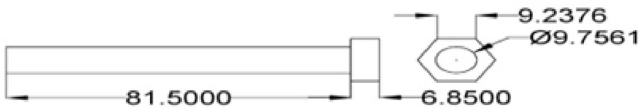
Leg Base-2D



Leg Base-3D

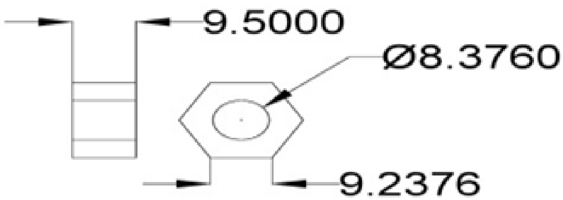


Bolt-2D

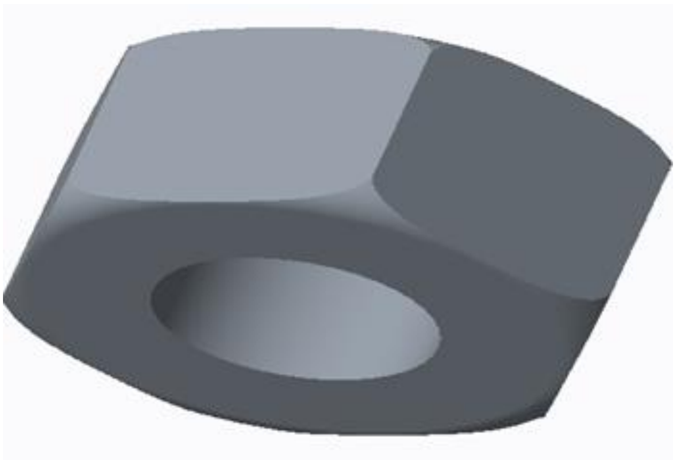


Bolt-3D

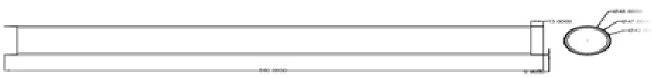
Nut-2D



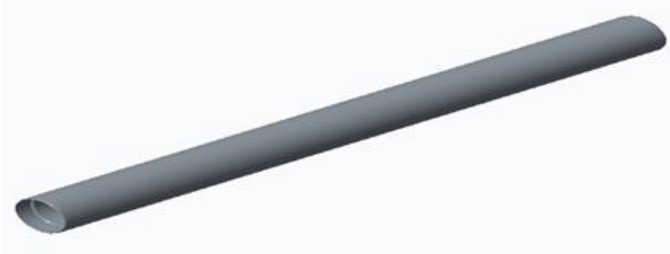
Nut-3D



Roller Leg Assembly



Roller-2D



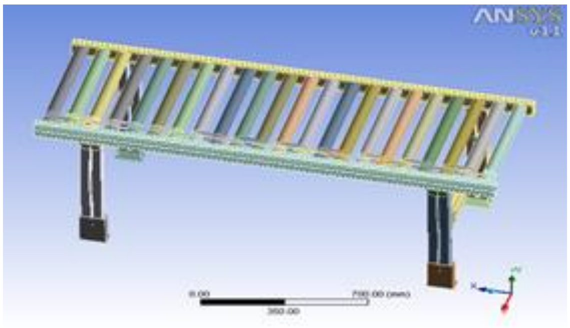
Roller-3D

Roller Assembly

IV. ANALYSIS

STRUCTURAL ANALYSIS

1. Importing the Model:
In this step the PRO/E model is imported into ANSYS workbench as follows:
In utility menu file option and select import external geometry and open file and click on generate. To enter into simulation module click on project tab and click on new simulation.



Importing Geometry

2. Defining Material Properties:

To define material properties for the analysis, following steps are used

Chose the main menu, select the model and create new material enter the properties again select simulation tab and select material

3. Defining Element Type:

To define type of element for the analysis, these steps are to be followed:

Chose the main menu, select type of contacts and then click on mesh-right click-insert method

Method - Tetrahedrons

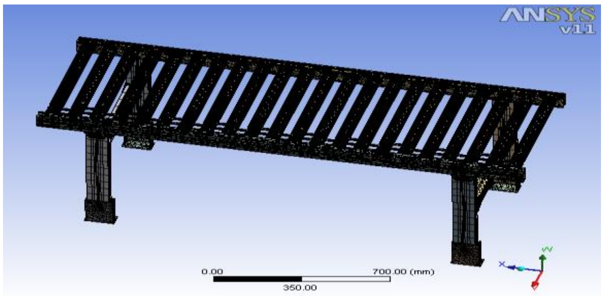
Algorithm - Patch Conforming

Element Midsize Nodes – Kept

4. Meshing the model

To perform the meshing of the model these steps are to be followed:

Chose the main menu click on mesh- right click-insert sizing and then select geometry enter element size and then click on generate mesh.

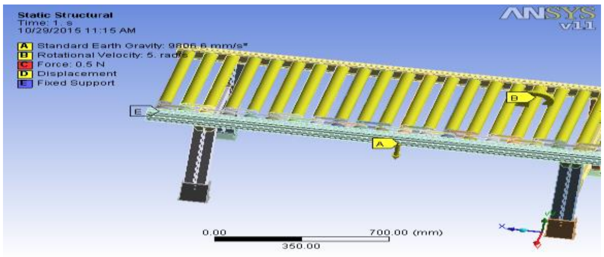


Mesh Generation

5. Applying Boundary conditions and Loads:

To apply the boundary conditions on the model these steps are to be followed:

Chose the main menu, click on new analysis tab select static structural click on face and then select face of the geometry-right click- insert-fixed support. Choose the main menu- select face and click on face of geometry- right click – insert – force



Boundary conditions and Load applications

6. Solving the Model:

To solve the model these steps are to be followed:

Choose the main menu, click on solution – insert – stress

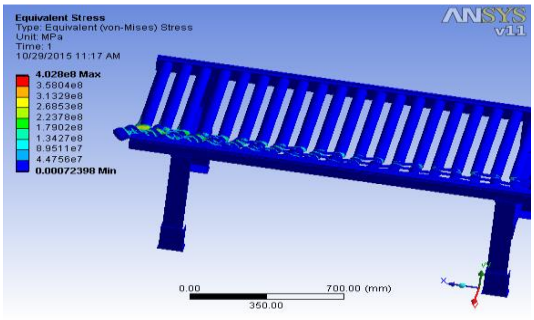
Click on solution – insert – deformation – total deformation

Click on solution – right click – evaluate results – solve

7. Results

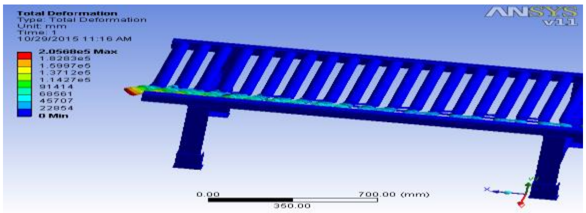
The main menu is chosen and then click on stress and deformation. The stresses and deformations will be displayed showing the maximum and minimum values.

Structural Analysis Results:



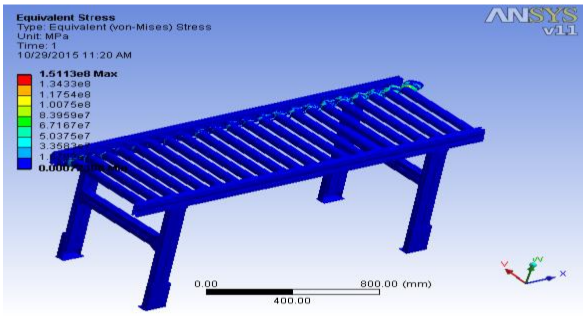
High Carbon Steel Equivalent stress

When we conducted static structural analysis on roller conveyor system of having E-Glass/Epoxy material the minimum von-misses stress is 0.07 MPa and maximum total deformation is 402.8 MPa.



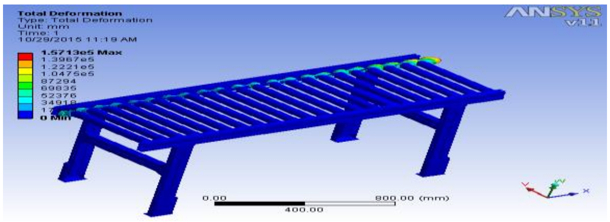
High Carbon Steel-Total Deformation

When we conducted static structural analysis on roller conveyor system of having high carbon steel material the minimum total deformation is 0 mm and maximum total deformation is 0.205 mm.



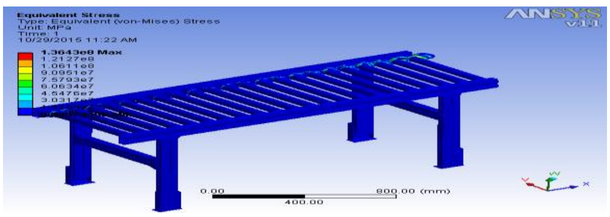
E-Glass/Epoxy- Equivalent stress

When we conducted static structural analysis on roller conveyor system of having E-Glass/Epoxy material the minimum von-misses stress is 0.07 MPa and maximum total deformation is 151.1 MPa.



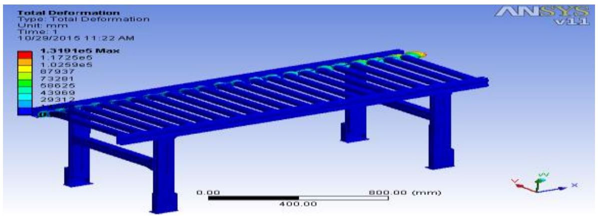
E-Glass/Epoxy - Total Deformation

When we conducted static structural analysis on roller conveyor system of having E-Glass/Epoxy material the minimum total deformation is 0 mm and maximum total deformation is 0.157 mm.



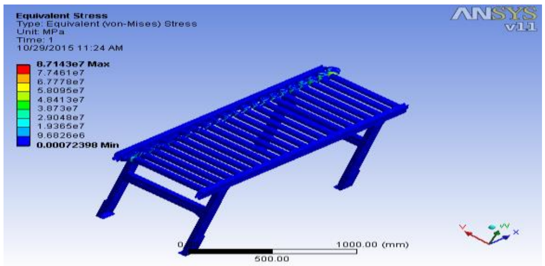
S –Glass/Epoxy- Equivalent stress

When we conducted static structural analysis on roller conveyor system of having S-Glass/Epoxy material the minimum von-misses stress is 0.07 MPa and maximum total deformation is 136.4 MPa.



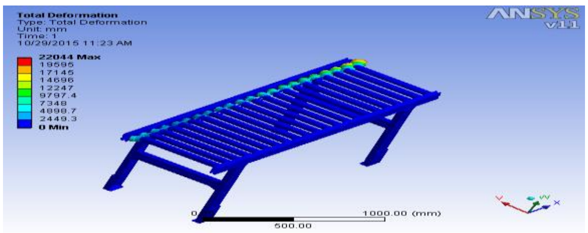
S-Glass/Epoxy- Total Deformation

When we conducted static structural analysis on roller conveyor system of having S-Glass/Epoxy material the minimum total deformation is 0 mm and maximum total deformation is 0.131 mm.



Carbon/ Epoxy Equivalent stress

When we conducted static structural analysis on roller conveyor system of having Carbon/Epoxy material the minimum von-misses stress is 0.07 MPa and maximum total deformation is 871.4 Mpa.



Carbon/Epoxy Total Deformation

When we conducted static structural analysis on roller conveyor system of having Carbon/Epoxy material the minimum total deformation is 0 mm and maximum total deformation is 0.22 mm.

The comparison of stress and deformation results for materials E-glass, Carbon fiber, S-glass and High carbon steel at two loads.

In below table Comparison of Stress

S.NO	Materials	Von-Mises Stress (MPa)	Total Deformation (mm)
1	E-glass	151.13	0.1571
2	Carbon Epoxy	871.43	0.220
3	S-glass	136.4	0.1319
4	High carbon steel	402.8	0.20568

Total Deformation results for 4 materials

V. RESULTS AND DISCUSSION

After conducting the static structural analysis on four different materials along with the existing material of a roller conveyor system the results of total deformation and von-mises stresses are given below:

- The stress and deformation for the material E-Glass/Epoxy are 151.13 MPa and 0.1517mm.
- The stress and deformation for the material s-Glass/Epoxy are 136.4 MPa and 0.1319 mm.
- The stress and deformation for the material Carbon/epoxy are 871.43 MPa and 0.220 mm.
- The stress and deformation for the material High carbon steel are 402.8 MPa and 0.205mm.

VI. CONCLUSION

Reducing weight and increasing strength of products are high research demands in the world. Composite materials are getting to be up to the mark of satisfying these demands. The composite roller conveyor have high strength to weight ratio for the same load carrying capacity with same dimensions as that of steel Rollers. The composite materials used for analysis are E-glass/epoxy, S-glass/epoxy and Carbon/Epoxy. Initially static analysis has been performed on the Roller conveyor system with the above three materials along with existing material.

From the structural analysis it is found that at mentioned load condition the total deformation in High carbon steel Roller system is 0.20568 mm and the corresponding deformations in E-glass/epoxy, S-glass/epoxy and Carbon/epoxy Rollers are 0.1571 mm, 0.1319 mm and 0.220 mm. The von-misses stress in the high carbon steel Roller is 402.8 MPa and the corresponding von-misses stress in E-glass/epoxy, S-glass/epoxy and Carbon/epoxy rollers are 151.13 MPa, 136.4 MPa and 871.43 MPa.

A comparative study has been made between steel and composite roller conveyor with respect to strength and weight. The weight reduction is found to be 63.69% for E-glass/Epoxy, 64.27% for S-glass/Epoxy, 74.59% for Carbon/epoxy over High carbon steel roller system.

Finally it is concluded that S-Glass/Epoxy composite Roller is suggested as replacement to the High carbon steel Rollers, since the deformation and stress concentration is lowest at the main rollers system.

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