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Design and Analysis of a Roller Conveyor System for Weight Optimization and Material Saving

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ABSTRACT : Over the years a lot of work has done and is still continuing with great effort to save weight and cost of applications. The current trend is to provide weight/cost effective products which meet the stringent requirements. The aim of this paper is to study existing conveyor system and optimize the critical parts like roller, shafts, C-channels for chassis and support, to minimize the overall weight of assembly and material saving.

Keyword : Optimized design, APDL programming, material handling systems.

I. INTRODUCTION

A. 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 [1]. 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 [4].

- 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.

Fig. 1. Conveyor Systems.

There are a variety of options available for running conveying systems [3], including the hydraulic, mechanical and fully automated systems, which are equipped to fit individual needs.

Conveyor systems are commonly used in many industries, including the automotive, agricultural, computer, electronic, food processing, aerospace, pharmaceutical, chemical, bottling and canning, print finishing and packaging. Although a wide variety of materials can be conveyed, some of the most common include food items such as beans and nuts, bottles and cans, automotive components, scrap metal, pills and powders, wood and furniture and grain and animal feed [3]. Many factors are important in the accurate selection of a conveyor system. It is important to know how the conveyor system will be used beforehand. Some individual areas that are helpful to consider are the required conveyor operations, such as transportation, accumulation and sorting, the material sizes, weights and shapes and where the loading and pickup points need to be [6] (Fig. 1).

B. Types of Conveyor Systems

- Gravity Conveyor systems

- Powered Belt Conveyor systems

- Pneumatic conveyor systems

- Vibrating conveyor systems

- Flexible conveyor systems

- Vertical conveyor systems and spiral conveyors

- Live Roller Conveyor systems

II. PROBLEM DEFINITION

The aim of this project is to redesign existing gravity roller conveyor system by designing the critical parts (Roller, Shaft, Bearing and Frame), to minimize the overall weight of the assembly and to save considerable amount of material.

Gravity roller Conveyor has to convey 350 kg load, 30 inch above ground and inclined at 4 degree. Fig. 2 shows roller conveyor assembly.

Components of conveyor are as follows :

S. No.	*Component*	*Material*	*Qty.*
1	C-Channels for Chassis	ISMC 100	2
2	Rollers	Mild Steel	15
3	Bearing	Std.	30
4	C-Channels for Stand	ISMC 100	4
5	Shaft	Mild Steel	15

Design roller conveyor to reduce weight.

III. OBJECTIVE OF THE STUDY

The following are the objectives of the study :

1. Study existing roller conveyor system and its design.
2. Geometric modeling [7] of existing roller conveyor.
3. To generate parametric model using ANSYS Parametric Design Language (APDL) program.
4. To carry out linear static, modal, transient and optimization analysis of existing roller conveyor.
5. Modification of critical conveyor parts for weight optimization.
6. To carry out Analysis of Modified design for same loading condition.
7. Recommendation of new solution for weight optimization.

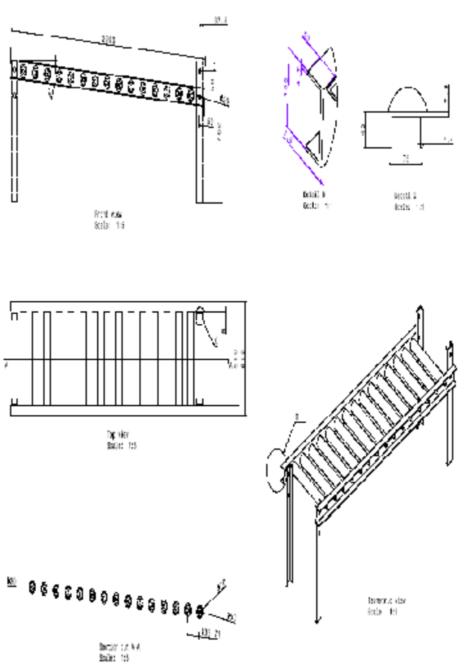

Fig. 2. Gravity Roller Conveyor Assembly.

IV. SCOPE OF PRESENT STUDY

1. Check design of existing conveyor system.
2. Simulation method applied to optimize parameters web thickness, flange thickness, web height, roller thickness and shaft diameter.
3. ANSYS APDL codes applied for linear static, modal, transient and optimization analysis.
4. 150 simulations for linear static Analysis.
5. 150 simulations for Modal Analysis.
6. Optimization of conveyor assembly for weight reduction.
7. Comparison between existing and optimized design.

V. STUDY OF THE EXISTING ASSEMBLY OF CONVEYOR SYSTEM

A. Total Weight of Existing Conveyor Assembly

S. No.	*Name of Component*	*Weight (Kg)*
1	C- Channel for Chassis	36.7548
2	Rollers	111.1181
3	Shafts	20.7421
4	Bearing	2.994
5	C-Channel for Supports	20.81
	Total weight of assembly	**192.419 kg**

B. Geometric Modeling

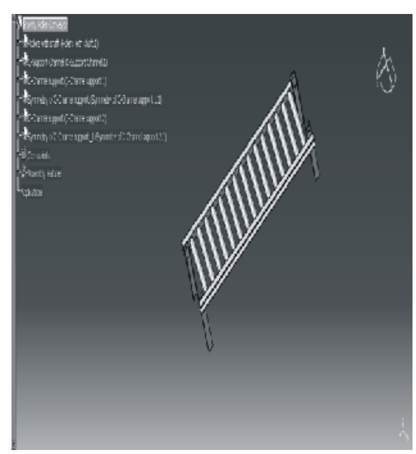

Fig. 3. Geometrical modeling using Catia.

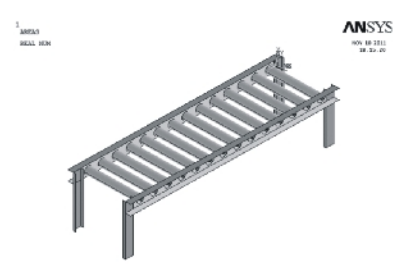

Fig. 4. Geometrical modeling using ANSYS APDL codes.

C. Finite Element Modeling

Fig. 5. Finite element mesh of the model.

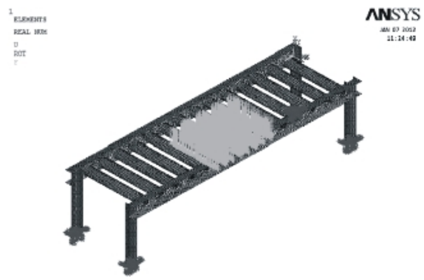

Fig. 6. A static load of 3500 N (approx 350 kg) is applied on the 4 rollers at the centre, as the deflection will be maximum, when the load is applied at the centre.

D. 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 [2, 4, 8] 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.

Critical load condition : Load act on any four rollers hence by considering 350 kg load act on four rollers maximum deflection, maximum stress values are checked for existing design.

E. Procedure of Static analysis consists of these tasks

1. Build the Model
2. Set Solution Controls
3. Set Additional Solutions Options
4. Apply the loads
5. Solve the Analysis
6. Review the results.

Results for static analysis :

- Weight = the weight of the model is 203.1 kg

- Maximum deflection plot shown in Fig. 7.

- Maximum stress plot Fig. 8

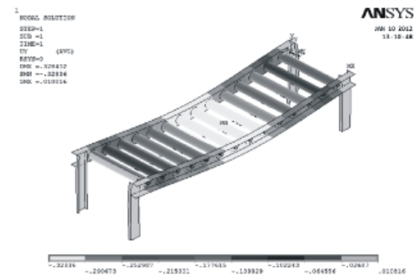

Fig. 7. Deflection plot.

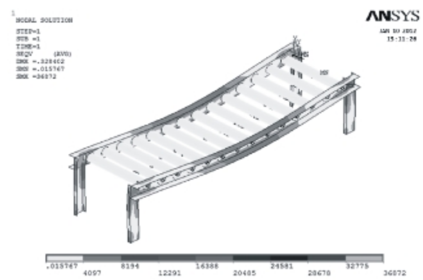

Fig. 8. Stress Plot.

F. Modal analysis

- Modal analysis is carried out to find natural frequency and mode shapes.
- As the loading will be in vertical direction (gravity) the mode shape which will show movement in vertical direction is important.

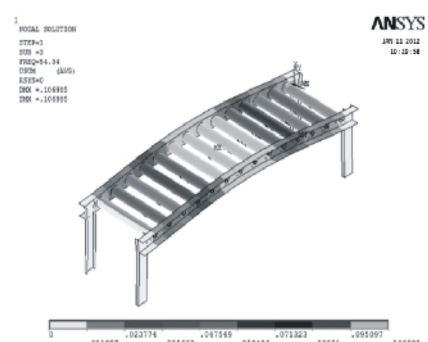

Fig. 9. Critical Mode Shape.

Result from Modal analysis :

- From the results it is clear that the third mode shape will have maximum motion in vertical direction. So third natural frequency should be greater than the excitation frequency.
- Third natural frequency is 54.34 Hz.

VI. NEED OF OPTIMIZATION

As factor of safety of C-Channels and Rollers is very high there is scope of weight reduction in this component.

A. Selection of Critical Parameter

- Flange width.
- Flange thickness.
- Web height.
- Web thickness.
- Roller Outer diameter.
- Roller thickness.

B. APDL Codes for Simulation

- "Do loop" is formed for to calculate effect of critical parameter on various factors like maximum deflection, stress, weight, first, second and third natural frequency.
- For each parameter 25 simulations are carried out.
- Total 150 Simulations carried out.

VII. OPTIMIZED DESIGN

- Selecting available which is similar to optimized design.
- Select ISJC 100 and ISJC 75 C-channels for chassis and supports respectively.
- Roller Outer diameter is 60 mm and roller thickness 5 mm.

S. No.	***Name of component***	***Max. Bending Moment (Nm)***	***Max. Bending Stress N/mm^2***	***Deflection (mm)***	***Actual factor of safety***
1	C-Channel for Chassis	858.375	34.139	1.108	14.1389
2	Rollers	26.8242	9.95	1.605	59.2955
3	C-Channel for Supports	224.256	8.1567	0.0501	31.8353

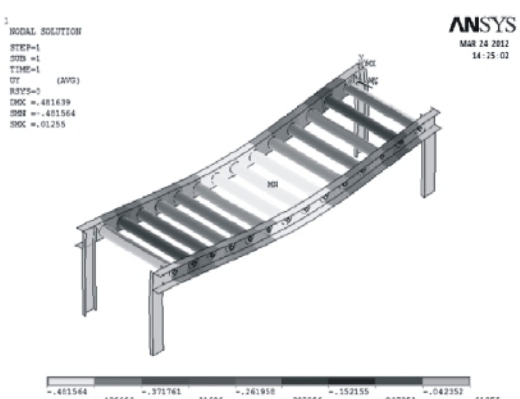

Fig. 10. Linear Static Analysis of Optimized design: Deflection plot.

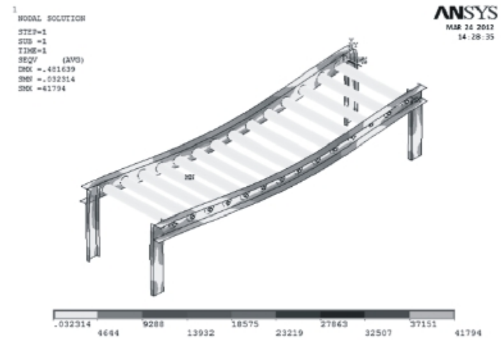

Fig 11. Stress Plot.

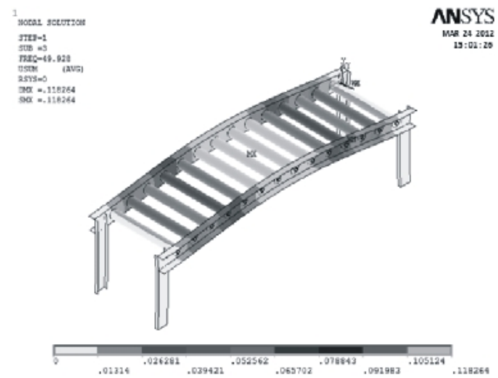

Fig. 12. Critical Mode Shape of Optimized design.

VIII. RESULT

Effect of Optimized Design :

S. No.	***Name of Component***	***Weight (Kg)***
1	C-Channels for Chassis	25.020
2	Rollers	71.96
3	Shafts	20.7421
4	Bearings	2.994
5	C-channels for Supports	12.187
	Total Weight of Conveyor	132.9031

Design	***Max. Def (mm)***	***Natural Freq. (Hz)***	***Max. Stress (N/mm^2)***
Existing	0.3284	54.34	36.872
Optimized	0.4816	49.928	41.794

A. Weight reduction due to Optimization

Design	***Weight (Kg)***	***% Material required compared to existing design***	***% Material save compared to existing design***
Existing	192.419	100	--
Optimized	132.9031	69.069	30.931

IX. CONCLUSIONS

- Existing design calculation shows the factor of safety is very greater than requirement and there is a scope for weight reduction.
- Critical parameter which reduces the weight is C-channels, roller outer diameter and roller thickness.
- Though value of deflection, stress is more in case of Optimized design, but it is allowable.
- 30.931 % of weight reduction due to Optimized design.

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