Redesign of Roller Conveyor System for Weight Reduction

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Abstract— A conveyor system is a common piece of mechanical handling equipment that moves materials from one location to another. This work presents an application of concept of concurrent engineering and the principles of design for manufacturing and design for assembly, several critical conveyor parts were investigated for their functionality, material suitability, strength criterion, cost and ease of assembly in the overall conveyor system. The existing system will be redesign and optimize for weight, resulting into material saving by modifying and analysing the critical conveyor parts. Detailed results will be found in the final part of the dissertation.

Key words: Conveyor system, Analyse, Geometrical Modelling, optimization

I. INTRODUCTION

Conveyor is applied to many gravity materials, handling various packaged materials efficiently for distances as short as 2 ft. or as long as 100 ft. or more. Any item from light bulbs to bagged cement to heavy castings can be moved on gravity. Gravity conveyors are divided into two categories.

Roller conveyor is not subjected to complex state of loading still we found that it is designed with higher factor of safety. If we redesigned critical parts e.g. Roller, Shaft, Bearing & Frame etc. then it is possible to minimize the overall weight of the assembly. Powered belt conveyors are considerable long (9000 meter to 10000 meter) as compared to roller conveyor. So we can achieve considerable amount of material saving if we apply above study related to roller conveyor to this belt conveyor.

A production line is commonly arranged in a series of workstations and each workstation consists of one or more parallel machines of the same type. To support the loading and unloading tasks for the parallel machines, the conveyors are generally employed as material handling equipment in modern industry.

II. LITERATURE REVIEW

M. A. Alspaugh (2004) presents latest development in belt conveyor technology & the application of traditional components. Examples of complex conveying applications along with the numerical tools required to insure reliability and availability are reviewed. This paper gives reference of Henderson PC2 which is one of the longest single flight conventional conveyors in the world of 16.26 km. But a 19.1 km conveyor is under construction in the USA now, and a 23.5 km flight is being designed in Australia. Other conveyors 30-40 km long are being discussed in other parts of the world. [1]

DimaNazzal& Ahmed El-Nashar [2007]discussed literature related to models of conveyor systems in semiconductor fabs. A comprehensive overview of simulation-based models is provided. They also identify and discussed specific research problems and needs in the design and control of closed-loop conveyors. It is concluded that new analytical and simulation models of conveyor systems need to be developed to understand the behavior of such systems and bridge the gap between theoretical research and industry problems.[2]

Chun-HsiungLan [2003]discusses multi conveyor systems in supporting machine loading and unloading. It not only meditates the concept of balancing the number of parallel machines, the conveyor speed for adjacent pallets, the overall relevant costs and the NBN Sinhgad School of Engineering M. E. (Mechanical) (Design Engineering) 13 determination of the number of conveyors into the objective, but also develops a two-staged method to optimize the combined problem to reach a maximum profit.Moreover, the computerized sensitivity analyses are discussed in this study. [3]

A. Comments

Review of literature gives idea about various types of analysis and optimization techniques used and the information about conveyor systems and related applications, types and various designs.

However it's clear from above literature survey that less work is done in optimization of conveyors, further for saving cost and if possible material also. So there is a need of system which provides solution that reduces costing and material through suitable optimization.

As lengths of such conveyors are very high and such systems are not subjected to critical/complex loadings saving will be higher one, so its fare to find optimized solution for such problems.

III. INTRODUCTION TO FINITE ELEMENT ANALYSIS

Finite Element Analysis (FEA) was first developed in 1943 by R. Courant, who utilized the Ritz method of numerical analysis and minimization of variation calculus to obtain approximate solutions to vibration systems. Shortly thereafter, a paper published in 1956 by M. J. Turner, R. W. Clough, H. C. Martin, and L. J. Topp established a broader Definition of numerical analysis. The paper centered on the "stiffness and deflection of complex structures". Fig.-1 below shows meshing of the turbine blade.

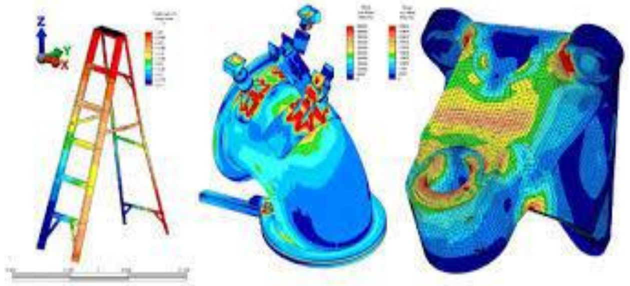

Fig. 1: FEA Analysis

There are generally two types of analysis that are used in industry: 2-D modeling, and 3-Dmodeling. While 2-D modeling conserves simplicity and allows the analysis to be run on a relatively normal computer, it tends to yield less accurate results. 3-D modeling, however, produces more accurate results while sacrificing the ability to run on all but the fastest computers effectively. Within each of these modeling schemes, the programmer can insert numerous algorithms (functions) which may make the system behave linearly or non-linearly. Linear systems are far less complex and generally do not take into account plastic deformation. Non-linear systems do account for plastic deformation, and many also are capable of testing a material all the way to fracture.

FEA uses a complex system of points called nodes which make a grid called a mesh (Figure -2). This mesh is programmed to contain the material and structural properties which define how the structure will react to certain loading conditions. Nodes are assigned at a certain density throughout the material depending on the anticipated stress levels of a particular area. Regions which will receive large amounts of stress usually have a higher node density than those which experience little or no stress. Points of interest may consist of: fracture point of previously tested material, fillets, corners, complex detail, and high stress areas. The mesh acts like a spider web in that from each node, there extends a mesh element to each of the adjacent nodes. This web of vectors is what carries the material properties to the object, creating many elements.

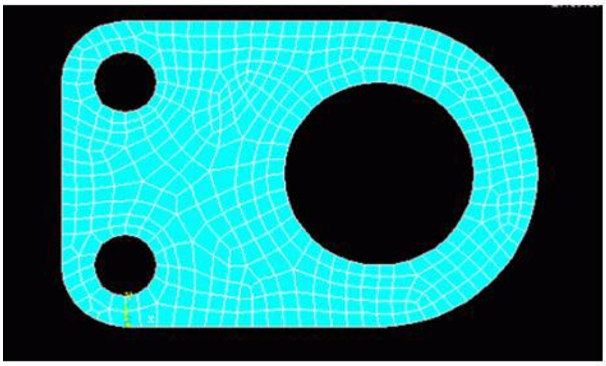

Fig. 2: meshing of plate

A wide range of objective functions (variables within the system) are available for minimization or maximization:

- Mass, volume, temperature
- Strain energy, stress strain
- Force, displacement, velocity, acceleration
- Synthetic (User defined)

There are multiple loading conditions which may be applied to a system. Point, pressure, thermal, gravity, and centrifugal static loads.

- Thermal loads from solution of heat transfer analysis
- Enforced displacements
- Heat flux and convection
- Point, pressure and gravity dynamic loads.

There are two main meshing methods: Free and Mapped.

A. *Free Mesh*

- Have no element shape restrictions.
- The mesh does not follow any pattern.
- Suitable for complex shaped areas and volumes.

B. *Mapped Mesh*

- Restricts element shapes to quadrilaterals for areas and hexahedra (bricks) for volumes.
- Typically has a regular pattern with obvious rows of elements.
- Suitable only for "regular" areas and volumes such as rectangles and bricks.

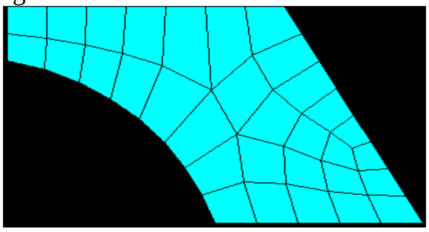

Fig. 3: Free Mesh

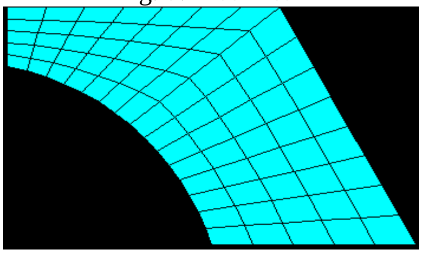

Fig. 4: Mapped Mesh

IV. MODELING AND MESHING

The geometric modeling is used to represent the geometry in terms of points, curves. It stores enough information to fully describe the boundaries and the topology of the object. Fig. below shows the geometric modeling of the structure with coordinate system used for Finite Element Analysis. During the present study, the geometry of the conveyor frame is developed using CATIA V5 R20. Geometric modeling is done in parametric way; so that effect of change in dimension on quantities can be obtained by changing the parameter only. Fig. 6.1 and 6.2 shows Geometric model created on Catia and ANSYS respectively.

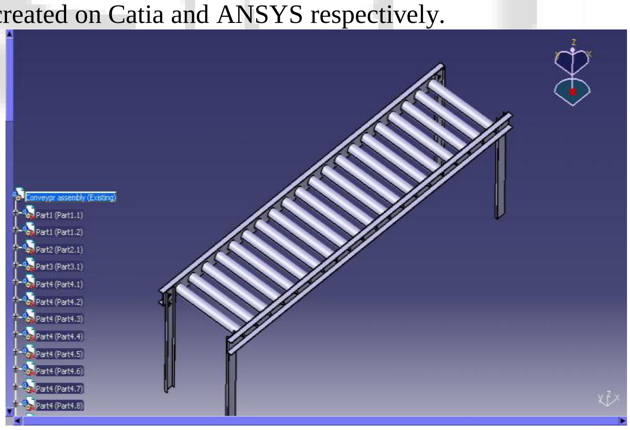

Fig. 5: Geometrical modeling using Catia

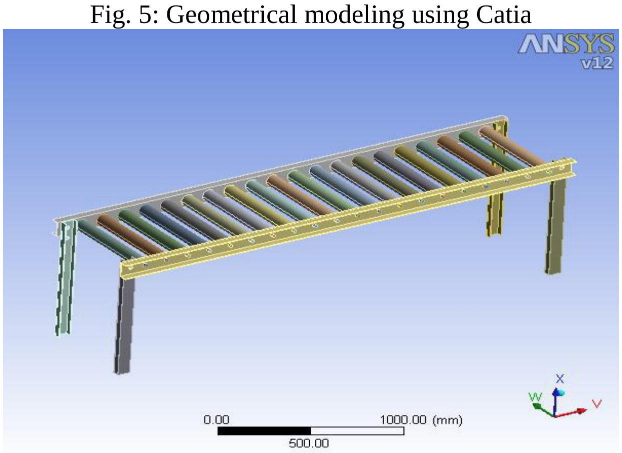

Fig. 6: Imported Model in ANSYS

V. FINITE ELEMENT ANALYSIS OF EXISTING DESIGN

A computerized numerical analysis technique used for solving differential equations to primarily solved mechanical engineering problems relating to stress analysis finite element analysis use a complex system of points called nodes which make a grid called mesh. This mesh is programmed to contain the material and structure properties which define how structure will react to certain loading condition. Nodes are assigned at certain density throughout the material depending on the anticipated stress level of particular area Regions which will receives large amount of stress usually have higher node density than those which experience little or no stress. Points of interest may consist of: fracture point of previously tested material fillets, corners, complex detail, and high stress areas. The mesh acts like a spider web in that from each node, there extends a mesh element to each of nodes. This web of vector is what carries the material properties to object, creating many elements.

Structural analysis consists of linear and nonlinear models. Linear models use simple parameters and assume that the material is not plastically deformed. Nonlinear models consist of stressing the material past its elastic capabilities.

Vibration analysis is used to test a material against random vibration, shock, and impact. Each of these incidences may act on the natural Vibrational frequency of the material which, in turn, may cause resonance and subsequent failure.

Thermal analysis calculates the temperature distribution and related thermal quantities in a system or component. Typical thermal quantities of interest are: The temperature distributions, amount of heat lost or gained thermal gradients and thermal analysis. Fluid analysis or computational fluid dynamics analysis is used to determine the flow of distribution and temperature of fluid.

Procedure of Static analysis consists of these tasks

- Build the Model
- Set Solution Controls
- Set Additional Solutions Options
- Apply the loads
- Solve the Analysis
- Review the Results

Results for static analysis,

1) Weight = the weight of the model is 342.46 kg.
2) Maximum deflection plot.
3) Maximum stress plot.

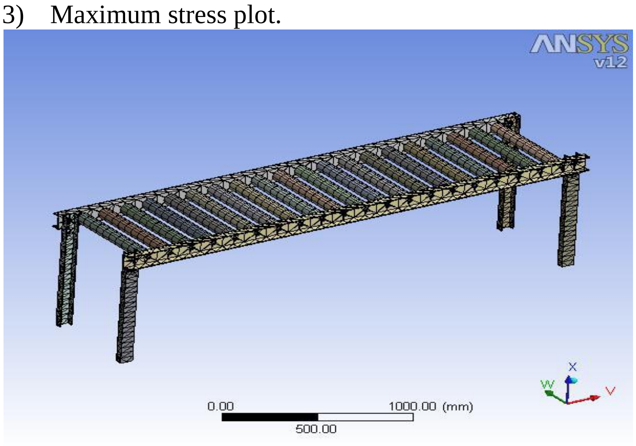

Fig. 7: Finite element mesh of the model (Isometric view)

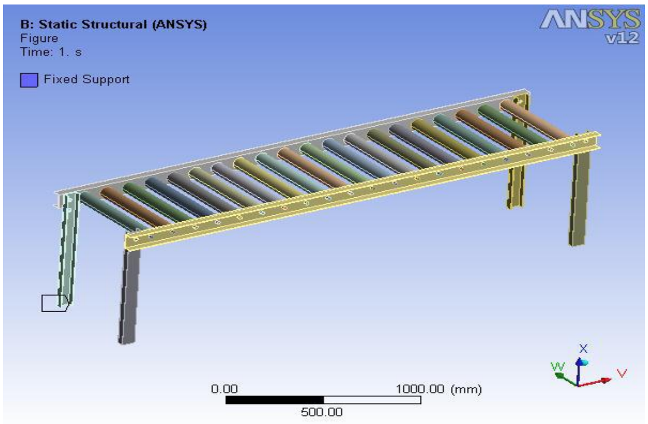

Fig. 8: Boundary Conditions - Fixed support at 4 legs and at support joints

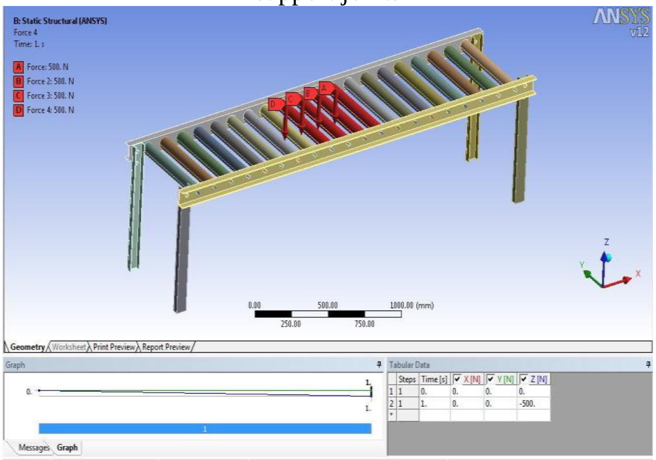

Fig. 9: A static load of 2000 N (approx 200 kg) is applied on the 4 rollers at the centre.

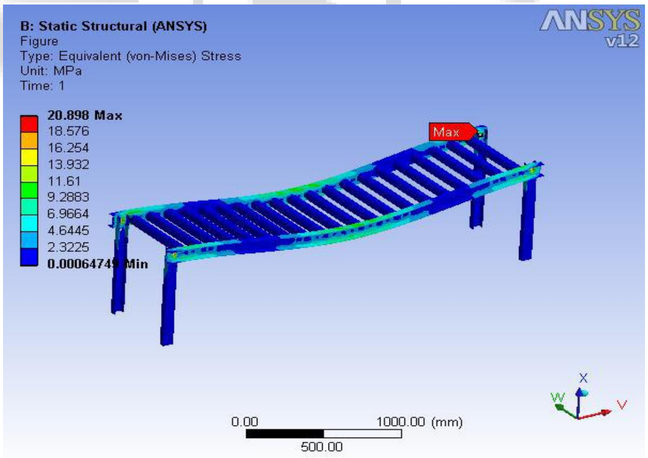

Fig. 10: stress plot for existing design

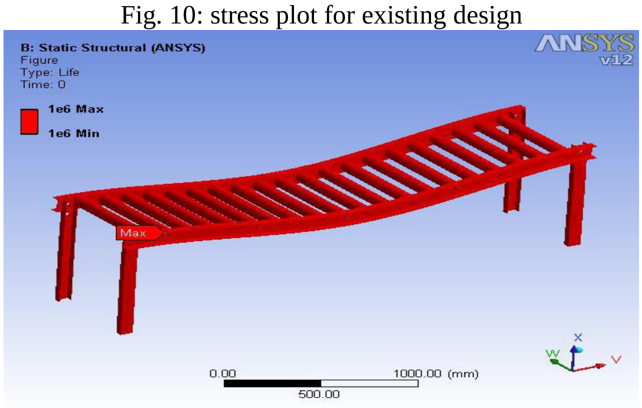

Fig. 11: life for existing design

VI. MODAL ANALYSIS

Modal analysis is used to determine the vibration characteristics (natural frequencies and mode shapes) of a structure or a machine component while it is being designed. It also serves as a starting point for another, more detailed analysis, such as a transient dynamic analysis a harmonic response analysis, or a spectrum analysis. Modal analysis also used to determine the natural frequencies and mode shapes of a structure. The natural frequencies and mode shapes are important parameter in the design of a structure for dynamic loading condition.

The general process for a modal analysis consists of these primary steps:

- Build the model.
- Apply loads and obtain the solution.
- Expand the modes.
- Review the results.

Result consists of: Natural frequencies, expanded mode shapes and Relative Stress and force distribution (if requested). Six mode shapes are shown in fig 7 to Fig. 8. First mode shape is more important as the direction of maximum deflection is along loading. So this can cause resonance. This frequency should be higher than the loading frequency.

VII. RESULT

Mode	Frequency [Hz]	Remark
1.	30.094	Critical – As its movement is in loading direction
2.	74.304	
3.	81.966	
4.	110.35	
5.	151.54	
6.	154.61	

Table 1: Modal Frequencies of existing system design

VIII. FUTURE SCOPE

1) Buckling analysis - Buckling analysis of support channels can be done to find maximum load.
2) Non-linear analysis - Material non-linearity can be considered to find more accurate results.
3) Thermal analysis can be considered for further study.
4) NVH (Noise vibration and Harshness) analysis possible for better and safer results.

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