Design and Strength Analysis of Load Roller Trolley Conveyor System

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Abstract - *In a car manufacturing industry it is required to move car body from one assembly line to other by using minimal cost and time consumption provided by the material handling system. Here an overhead load roller trolley conveyor system is used for the newly developing assembly line thus it is required to design and optimize the system in comparison to its existing one which is used in earlier plant. For this purpose three major components are designed namely trolley bracket, top frame and resting attachment.*

For the trolley bracket design and strength analysis is carried out for a load of 750kg. Similarly weight optimization is done for top frame for 1000kg load. On basis of the car design a resting attachment is designed for a load of 100kg. Static structural analysis is carried out to know the stress distribution in the structure. Preliminary theoretical validation is carried out to compare the FEM result. The analysis is carried out for 3 different components of the conveyor system. Theoretical validation shows that the FEM results are in conformance with the handmade calculations. The end results show that the components are under yield limit and the designs are outstandingly capable in handling the loads.

***Key Words*: Trolley, Top frame, Resting attachment, Finite element analysis, Von-Mises stress**

1. INTRODUCTION

A conveyor system is a very common product handling device. Conveyors provide companies with the ability to move product safely from one location to another without or little human intervention. Overhead trolley conveyor systems provide the same basic benefits of the common conveyor system except they provide exceptional use of floor space by using the airspace above manufacturing production areas to convey the products to predetermined pick-up or delivery station. These conveyors do not require the need for dedicated floor space for travel paths of the conveyor. By significantly reducing the need for floor space dedicated to product flow requirements, the overhead trolley conveyor systems will provide the ability for better and quicker product flow management as well as multiple tier or level drop-off and pick-up locations.[1]

Fig. 1 Actual Setup of Conveyor System

A material-handling system can be defined as movement, handling, storage and controlling of materials throughout the manufacturing process. The main purpose of using a material handling system is to ensure that the material in the right amount is carefully delivered to the desired destination at the right time at minimum cost. Material handling as such is not a production process and hence does not add to the value of the product but it costs 30-75% of the total product cost. An efficiently designed material handling system ensures the reduction in operation cost, manufacturing cycle time, MH cost, delay and damage [2]. It promotes productivity, flexibility, better utilization of manpower, increases material flow and automation in handling.

1.1 Design of MH Systems

A common approach to the design of MH systems (MHSs) is to consider MH as a cost to be minimized. This approach may be the most appropriate in many situations because, while MH can add real value to a product, it is usually difficult to identify and quantify the benefits associated with MH; it is much easier to identify and quantify the costs of MH (e.g., the cost of MH equipment, the cost of indirect MH labor, etc.). Once the design of a production process (exclusive of MH considerations) is completed, alternate MHS designs are generated, each of which satisfies the MH requirements of the production process. The least cost MHS design is then selected [3].

2. LITERATURE SURVEY

J. D. Tew, S. Manivannan, D. A. Sadowski, and A. F. Seila [1] were illustrate the simulation methodologies used in the design of Automated Material Handling Systems (AMHS) at

Intel wafer fabs for semiconductor manufacturing. The models used in AMHS design has categorized as AMHS models and production models. The AMHS models support the design of Interbay and Intrabay systems. The Inter bay systems handle the material flow between different bays (production centers). The Intrabay systems handle the material flow within the bays. The production models compliment the AMHS models. In modeling framework, they approaches AMHS and the production process models use a consistent set of assumptions. This de-coupling approach typifies the general philosophy to using simulation in design. Authors review the general model structures and simulation examples under these categories used in actual system implementations. In this paper the main purpose of using simulation is to ensure that the material handling system design meets material storage and transport requirements.

Prasad Karande and Shankar Chakraborty[2] have carried out the selection method for suitable MH equipment . They had proceed with multicriteria decision-making (MCDM) problem. As wide range of MH equipment is available today, for this complicated task they applied a multicriteria decision-making (MCDM) tool to select the most suitable MH equipment. They implement weighted utility additive (WUTA) method to solve an MH equipment selection problem. They have also observed a comparison of ranking obtained with the past researchers and found its potentiality, applicability, and accuracy to solve complex decision-making problems. They have explained that the WUTA method has a strong mathematical base and proficient of deriving more precise ranking of the considered alternatives. They have also concluded that it can also be useful for any decision-making problem with any number of selection criteria and feasible alternatives.

3. FE ANALYSIS OF MODELS

3.1 Existing Trolley

The CAD model of trolley is prepared in CATIA. Material used for trolley is mild steel, the model of which is as shown in figure 2. The model is meshed in Hypermesh software. The equivalent von mises stress observed in the component is well below the failure limit of the material from figure 3,

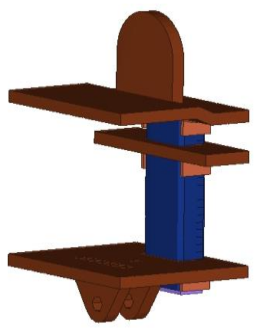

Fig. 2 Trolley CAD Model

As can be seen from the results; The load bearing capacity of the fixture is 750Kg and stresses observed are in bottom plate connection area. The stress values are within allowable limits. Therefore the design can be treated safe.

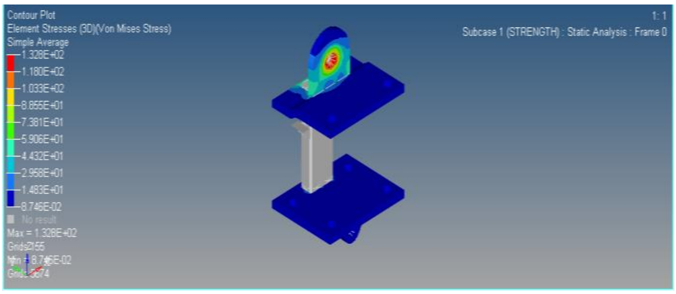

Fig. 3 Trolley Stress Plot

3.2 Optimized Trolley

The trolley's 4.8mm thick square tubes are way below the ultimate strength hence reducing the thickness to 4.5 mm. By incorporating these features CAD modeling and meshing is carried out for the optimized model, the result is as shown in figure 4,

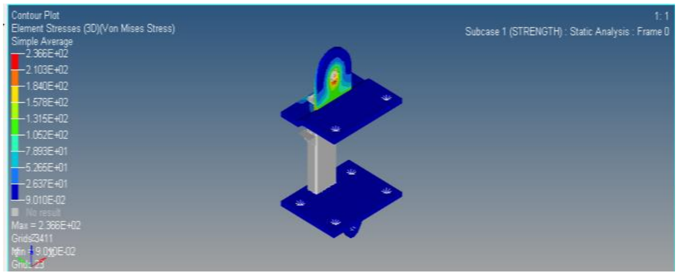

Fig. 4 Optimized Trolley Stress Plot

3.3 Existing Top Frame

Material used for top frame is mild steel, the model of which is as shown in figure 5,

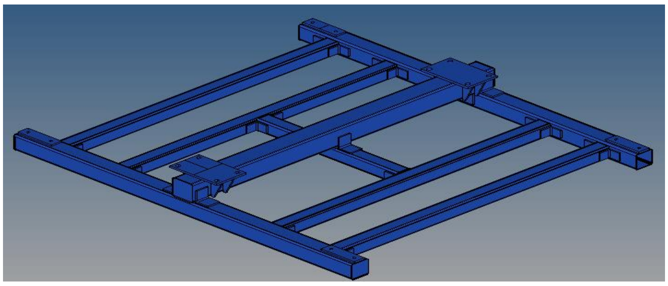

Fig. 5 Top Frame CAD Model

The equivalent von mises stress observed in the component is well below the failure limit of the material from figure 6.

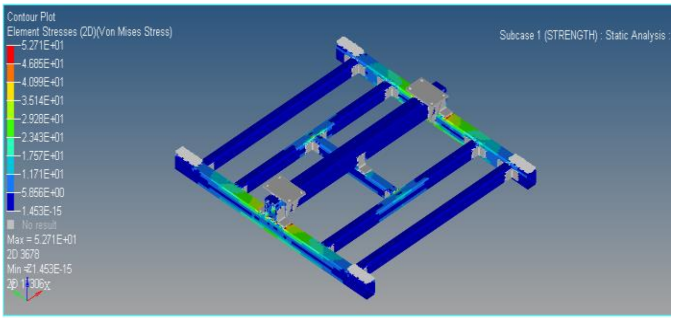

Fig. 6 Top Frame Stress Plot

3.4 Optimized Top Frame

The top frame's 5mm thick square tubes are way below the ultimate strength hence reducing the thickness to 4mm and eliminating square tubes at extreme ends. These changes are undertaken and the model's result is as shown in figure 7.

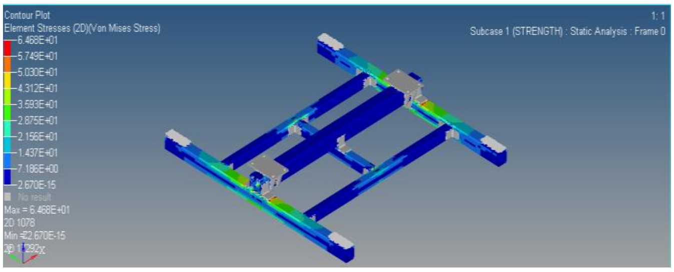

Fig. 7 Optimized Top Frame Stress Plot

3.5 Resting Attachment

Material used for resting arrangement is mild steel because this component is used as a material handling equipment in car body assembly in automobile industry for lifting and transporting of car body and requires good strength properties to withstand tensile loads and its model is as shown in figure 8.

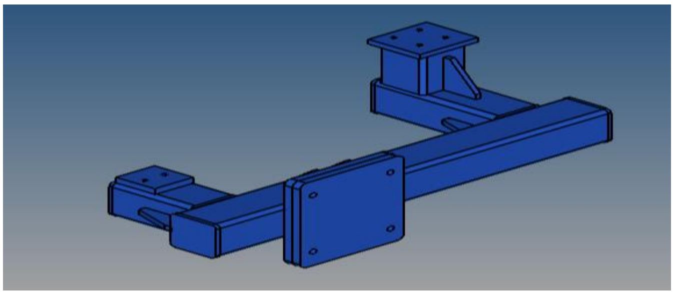

Fig. 8 Resting Attachment CAD Model

The equivalent von mises stress observed in the component is well below the failure limit of the material as shown in figure 9.

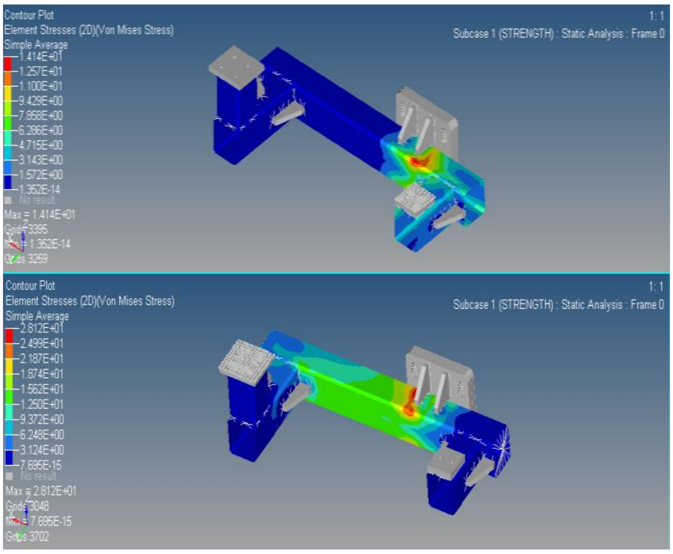

Fig. 9 Resting Attachment Stress Plot

4. THEORETICAL DESIGN CALCULATIONS

4.1 Top Frame

In order to calculate the stress in the structure, the rules of I.S. 3177:1999, I.S. 807:2006 and I.S. 800:2007 are applied.

$$M1 = \frac{\psi \times (W_d + W_t) \times \left(\frac{S - T_c}{2}\right)^2}{S} \quad (1)$$

$$M2 = 0.25 \times M1 \quad (2)$$

$$M3 = W_g \times S \quad (3)$$

Substituting the values in above equation we get the maximum stress value as 56.7 and 68.33 N/mm^2 for existing and optimized top frame respectively. Both the values are under yield limit and are considered safe.

4.2 Trolley

Using the formula,

$$\sigma_x = \frac{P}{A} + \frac{P \times e}{Z} \quad (4)$$

$$\tau_x = \frac{3 \times P}{2 \times A} \quad (5)$$

$$\sigma_{12} = \frac{\sigma_x}{2} \pm \sqrt{\left(\frac{\sigma_x}{2}\right)^2 + \tau_x^2} \quad (6)$$

$$\sigma_{von} = \sqrt{\sigma_1{}^2 + \sigma_2{}^2 - \sigma_1\sigma_2} \quad (7)$$

Thus on substitution we get von mises stresses as 138.89 and 238.06 N/mm^2 for existing and optimized trolley respectively. Both the values are under yield limit and are considered safe.

4.3 Resting Attachment

Using the equations,

Bending moment $M_b = P \times L$ (8)

Bending stress $\sigma_b = \frac{M}{Z}$ (9)

Axial stress $\sigma_a = \frac{P}{A}$ (10)

Maximum stress $\sigma_{max} = \sigma_a + \sigma_b$ (11)

The maximum stress value is under yield limit, thus safe for both the cases.

5. CONCLUSION

The objective of the present study is to provide a feasible solution for the material handling equipment problem in a car manufacturing plant. Here a load roller conveyor system assembly and mounting arrangement is suggested. From the analysis results following conclusions are drawn.

1. Static analysis is carried out for the geometry of trolley bracket which is in use for car manufacturing industry. The new design has 4.6 kg mass lower than the existing bracket and also von mises stress is under yield limit with lower deformation.
2. The optimized frame has lower deformation and is under yield limit and hence is considered safe.
3. The new resting attachment design is well under the prescribed yield limit with negligible amount of deformation.
4. All the FEM results are validated using theoretical calculations and thus are in good agreement.

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