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Design and Analysis of Material Handling System

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Abstract

In today's competitive global market, industries and manufacturing companies demand adjustable sizes, higher quality, flexibility, and shorter lead time types of products to be manufactured. Companies need to attain customer satisfaction and cost reduction in production operations. A material handling system is a way to accomplish this goal since they directly impact production. This study aims to design an in-house material handling system that could be efficient for the production it serves. The material handling system design was made to pick and place the head expander on the vibrating machine from the floor beside the machine. The vibration testing components are placed on the head expander where it is placed on the vibration machine to check the frequencies the component can absorb. This component is used in aerospace industries. The material used for building the material handling system is mild steel. By analyzing the possibilities from literature review and empirical study first problems and challenges related to material handling system are identified, then possible features that the system should possess are observed and design is built according to the selected features. The design of this material handling system is made by using solidworks software. The developed model is further analyzed by the boundary condition for total deformation when the constant load acts on the model at different places. Dynamic analysis to be made for the vibration absorbed by the material handling system. Here both static and dynamic analysis is made for the structural model using ANSYS WORKBENCH software.

Keywords: *Material Handling System, head expander and vibrating machine, Solid works 3D Cad software, ANSYS WORKBENCH software, static and dynamic analysis, mild steel material.*

1.0 Introduction

It is proposed to procure a material handling unit to load and unload the head expander on the vibration machine. This handling unit shall be used to lift and position the head expander from the ground to the top of the armature of the Vibration machine during the Z-direction vibration test. The handling unit shall be mounted on rails for free movement with hydraulic pads to prevent toppling of the unit while operating. Unit shall move in the horizontal and vertical direction along with manual rotation options, which will provide the user to lift the head expander and handle it smoothly. Necessary safety features to be incorporated during movement/rotation of trolley with the load. Head expanders are commonly used for vertical environmental testing. The purpose of the head expander is to extend the surface area of the shaker top to accommodate units under test (UUTs) with large dimensions for mounting and testing. One of the key parameters is the working frequency range associated with each head expander. The upper frequency is often used instead of the first resonance frequency of the head expander in vibration control tests. For vibration shaker testing, you can expand the mounting footprint. Shaker users can test objects that are larger than those that can be directly attached to the shaker platform because of the broader surface.

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Short-distance travel occurs within the bounds of a facility, such as a plant or a warehouse, as well as between a building and a transit agency. Material handling is the science of transporting, packing, and storing substances in any form. Material handling, on the other hand, now employs 35 per cent of the workforce, occupies 45 per cent of the industrial area, and consumes 80-90 per cent of production time. In some cases, the ideal technique of handling material may not necessitate the use of machinery. In recent years, material handling technologies and equipment types have grown dramatically, including robots, automated guided vehicles, high-rise storage retrieval systems, computerized picking systems, and computer-controlled conveyor systems. Material handling systems have become an acknowledged feature of today's industrial systems, and they are increasingly contributing to the plant's productivity.

However, given the large selection of material handling equipment available today, the optimal equipment option for a certain manufacturing scenario must be selected. Several scholars have proposed various criteria for selecting material handling equipment for a certain activity. Only a handful had used analytical approaches to choose the right material handling equipment for a certain application. The most significant factors were determined in the material handling equipment selection, which may vary from task to task. A few proposed approaches for drawing motion trajectories and determining path interferences using computer-aided technology to achieve numerous goals.

Material handling is frequently viewed as a cost to be reduced when designing material handling systems. While material handling can add genuine value to a product, it is often difficult to identify and quantify the benefits of MH; it is much easy to identify and quantify the expenses of material handling (e.g., the cost of material handling equipment, the cost of indirect material handling labour, etc.). After the design of a production process (excluding material handling considerations) is completed, many material handling system designs are developed, each of which meets the MH requirements of the production process. After that, the most cost-effective material handling system design is chosen.

2.0 Methodology

2.1 Equipment and System Challenges in Material Handling

Although material handling equipment has numerous advantages, it also has several drawbacks.

- User safety: For business owners, user safety is a top priority. According to a recent study, contact with moving machinery was responsible for 9% of fatal injuries, whereas being struck by a moving vehicle or object was responsible for 31%. Handling, lifting, and moving were responsible for 21% of non-fatal workplace injuries, whereas being struck by a moving object was responsible for 10% of workplace accidents.
- Inadequate operating knowledge: There is currently a scarcity of skilled and experienced workers, making it harder to maintain a safe working environment. Higher labour expenses, attrition rates, human errors, and downtime result from a lack of such a workforce.
- Human error: Material handling is likewise plagued by human error, which frequently results in mistakes. As a result, tragic accidents, destroyed goods, and production downtime may occur.
- Labour cost: Because of the scarcity of competent workers, labour expenses rise when the turnover rate rises, thereby raising the cost of employee training. At the same time, it results in an inefficient workforce that frequently fails to fulfill output targets.
- Downtime and labour productivity: Accidental delays or equipment failure can potentially result in significant downtime. In today's globalized world, even a little outage can destabilize the entire supply chain, resulting in severe losses. Furthermore, more downtime equals less production.
- Material management: Inefficient manufacturing lines result from a lack of trained material handling labour. These inefficiencies could lead to a shortage of raw materials or an overstocking of product inventory. Overstocking reduces your cash flow and results in increased expenses to hold surplus resources, whilst interrupting raw material supply reduces your productivity.

2.2 Material Selection

Material handling is acknowledged to be a demanding task for operators in the manufacturing industry. This problem can be remedied by utilizing proper material handling equipment (MHE), such as forklifts, automated guided vehicles (AGV), and other similar devices. The physical effort and, in certain cases, the cognitive workload required to accomplish the procedures can be reduced by using such equipment. Having suitable MHE in a facility increases the efficiency of production activities as well as worker safety.

MHS design difficulties are heavily focused on the MHE selection problem in the literature. This challenge entails choosing the proper equipment for the task at hand. This is the primary emphasis of this project. The goal is to compare and contrast various MHE options using a variety of criteria (financial criteria, production criteria, etc.). Such an evaluation enables one to select a solution that meets the company's specific requirements. The research only focuses on a few limited sets of criteria, and the applicable criteria in most identified industrial contexts are many and difficult to combine. Furthermore, the importance of these factors differs from study to study. As a result, this paper's initial contribution is to identify and characterize all of these criteria.

Mild steel is an iron and carbon-based ferrous metal. It is a low-cost material with qualities that make it ideal for a wide range of engineering applications. Because of its high iron content, low carbon mild steel has good magnetic characteristics and is hence classified as ferromagnetic. Mild steel is used extensively in the manufacturing of machinery and automobiles. It is low-cost, adaptable in terms of cutting and coating operations, and weldable while preserving appropriate physical properties. It can be used to make frames, panels, and other similar products because of these qualities. Mild steel has become a popular material in a variety of industries due to its great qualities. Its unrivaled weldability and machinability have resulted in a massive expansion in its use.

2.3 Properties of Mild Steel

Table 1: Properties of mild steel

Properties	Values
Density	7870 Kg/m^3
Young's modulus	210000 Mpa
Poisson's ratio	0.303
Bulk modulus	140000 Mpa
Tensile Ultimate strength	440 Mpa
Tensile Yield Strength	370 Mpa
Shear Modulus	80000 Mpa

2.4 Chemical Composition

Table 2: chemical composition of mild steel

Element	Content
Carbon	0.29 %
Copper	0.20 %
Iron	98 %
Manganese	1.03 %
Phosphorous	0.040 %
Silicon	0.280 %
Sulfur	0.050 %

2.5 Design of Material Handling System

By looking into design constraints and considering the design model according to the dimensions available and within the constraints. Design of material handling system for pick and place type operation is done based on the space available at the workspace and considering the constraints of the workspace, this below design has been created and approved by the customer for manufacturing.

The design of the material handling system consists of a rectangular C Channel structure that is supported by 4 pillars. These pillars are fixed by grouting them to the ground. I Beam of dimension 100*50mm is placed in the C Channel by connecting it to the rollers. I beam is connected to the rollers where it moves front and back inside the c channel. I beam is made to move because the head expander is placed behind the machine so it has to move back and lift the head expander and place it on the vibrator shaker. The dimension of the 100*50 I beam is used because the head expander lifter hoist dimension and weight match the 100*50 I beam.

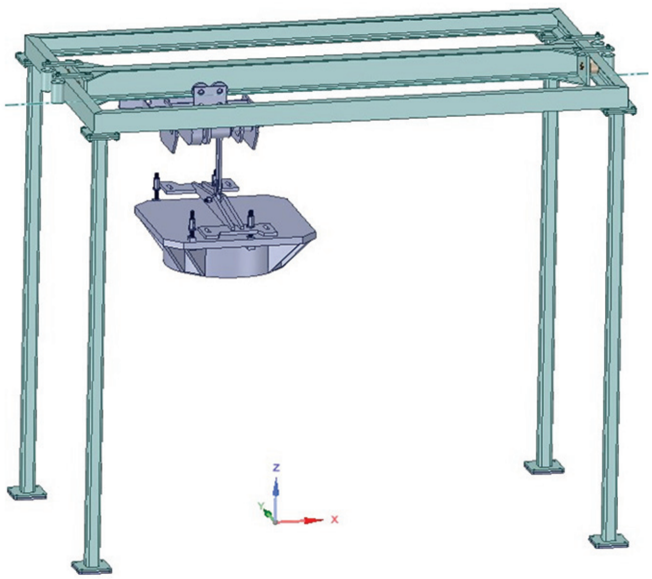


Figure 1: 3D model of material handling system

2.6 Meshing of Model

Meshing is one of the key components to obtaining accurate results from an FEA model. The elements in the mesh must take many aspects into account to be able to discretize stress gradients accurately. Any continuous object has infinite degrees of freedom and it is just not possible to solve the problem in this format. FEM reduces the degree of freedom

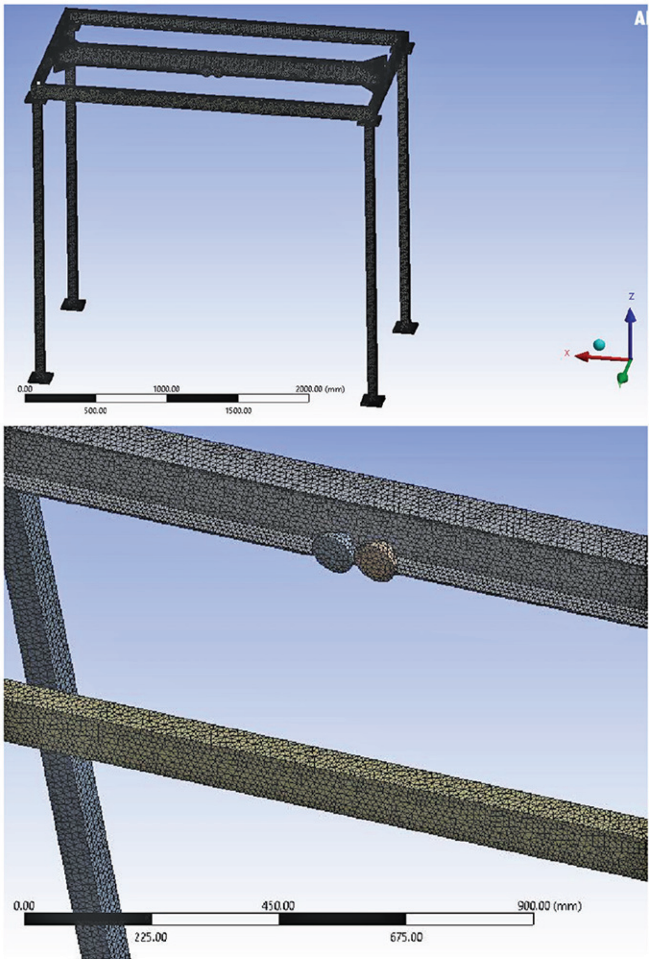


Figure 2: Meshing of 3d Model

from infinite to finite with the help of discretization or meshing. One purpose of meshing is to make the problem solvable using finite elements. By meshing, it will break up the domain into pieces, each piece represents an element.

3.0 Results and Conclusion

Analysis was carried out for different cases and loads are applied to the model at different dimensions. In the analysis the load of 1776.7N was applied to the I beam section of the model to find out the total deformation of the model and total von-mises stress to be obtained. For the model, both static and modal analysis has been done. In the static analysis, we found at each caseload was applied at a different position to find the total deformation and total stress acting on the model. Loads are applied at different positions because the loads are not at a constant position all the time there is a movement while loads are acting on the system. The analysis of total deformation and stresses acting on the system is shown below.

3.1 Static Analysis of Total Deformation

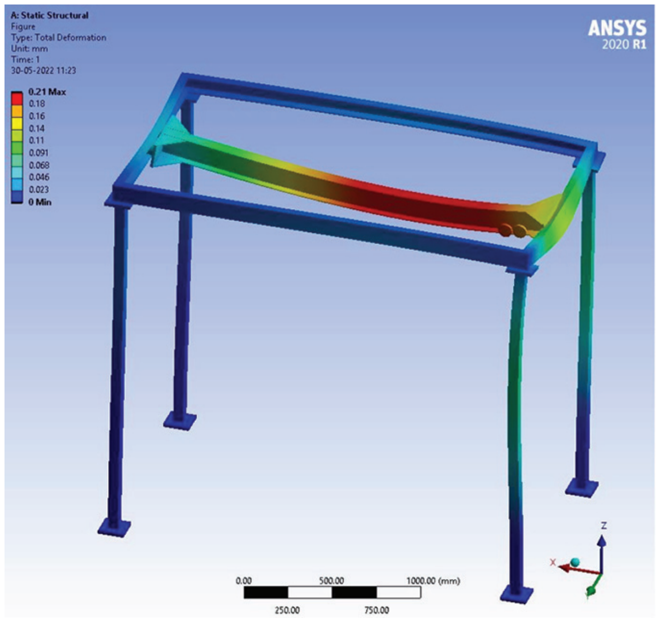


Figure 3: Total deformation for case 1

Table 3: Total deformation and von-mises stress values

Case	Position (mm)	Load In (N)	Total Deformation In (mm)	Von-Mises Stress (Mpa)
Case 1	0	1667.7	0.21	16.162
Case 2	501	1667.7	0.32	25
Case 3	Centre (1014)	1667.7	0.413	22.21

Case 1: when loads are applied at 0mm of I beam

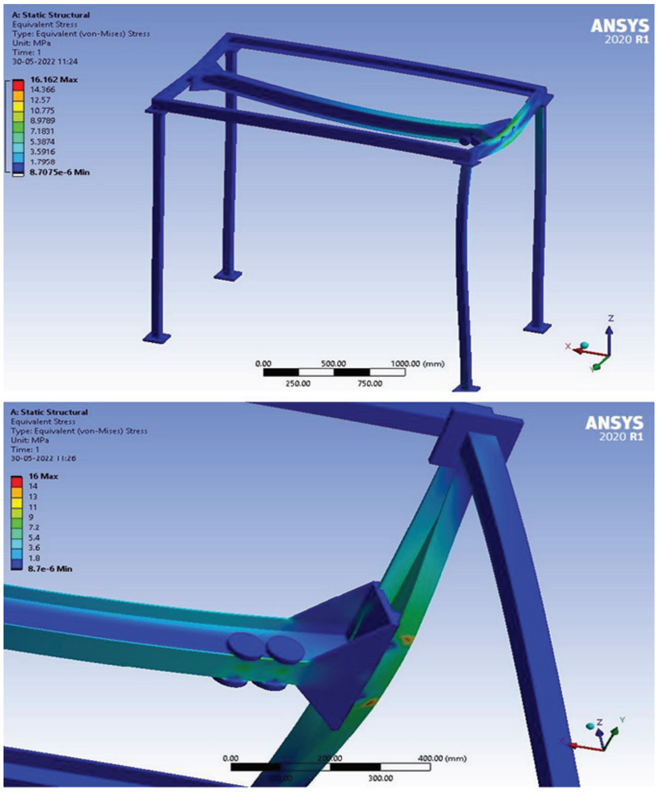


Figure 4: Von-mises stress for case 1

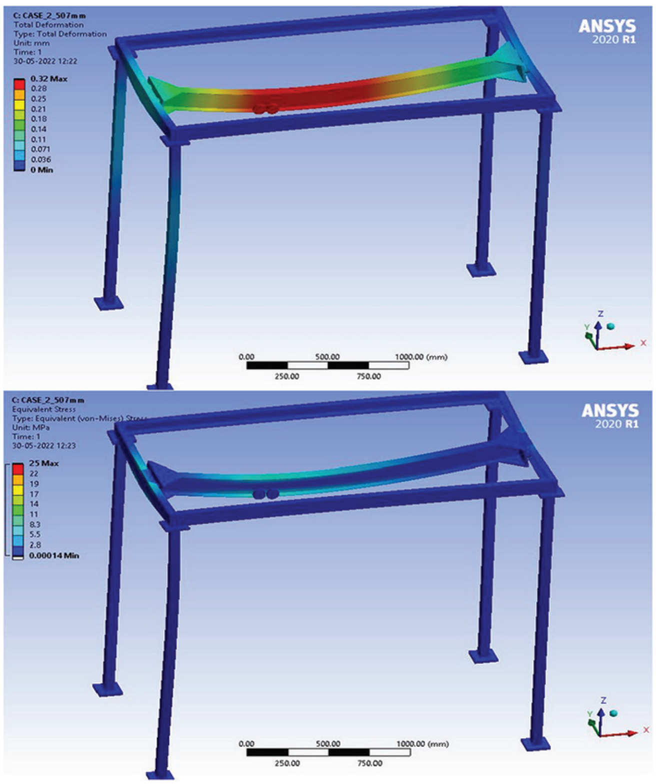


Figure 5: Total deformation for case 2

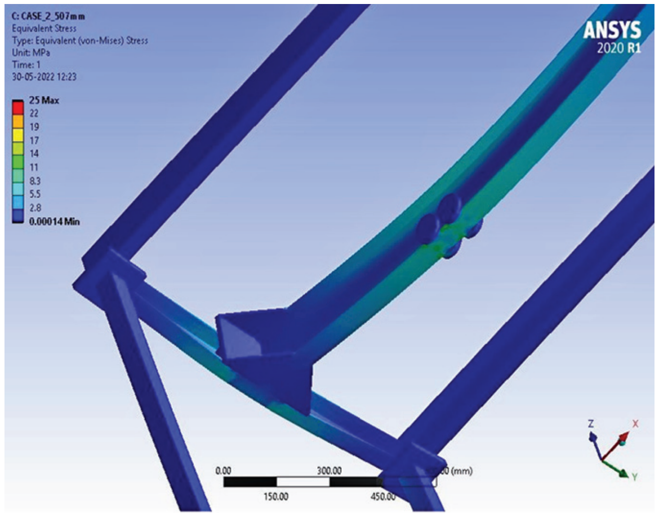


Figure 6: Von-mises stress for case 2

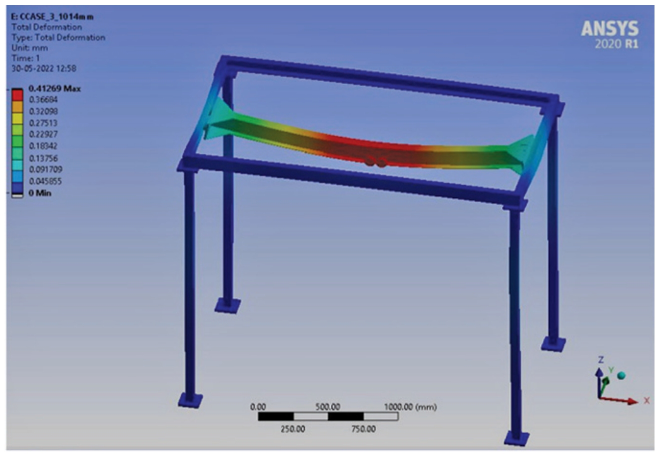


Figure 7: Total deformation for case 3

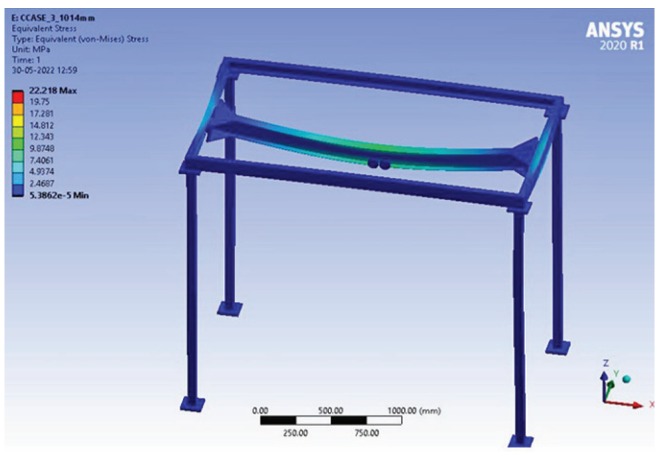


Figure 8: Von-mises stress for case 3

3.2 Modal Analysis

Model analysis of the model is done to find the total deformation of the system at different modes applied to the model. By applying different frequencies at different modes the model is checked for its total deformation. The mode shapes and different frequencies and different mode values are shown in Tables 4 and 5.

Table 4: Case 1: Frequencies for different mode values

	Mode	Frequency [Hz]
1	1.	7.4921
2	2.	7.6902
3	3.	11.593
4	4.	29.507
5	5.	37.255
6	6.	41.204
7	7.	50.231
8	8.	50.629
9	9.	57.232
10	10.	58.787

Table 5: Case 2: Frequencies for different mode values

	Mode	Frequency [Hz]
1	1.	7.6506
2	2.	7.8499
3	3.	11.263
4	4.	30.357
5	5.	36.042
6	6.	42.054
7	7.	51.306
8	8.	51.735
9	9.	56.047
10	10.	57.382

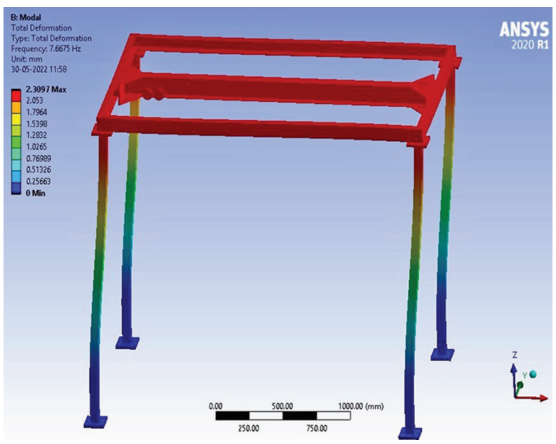
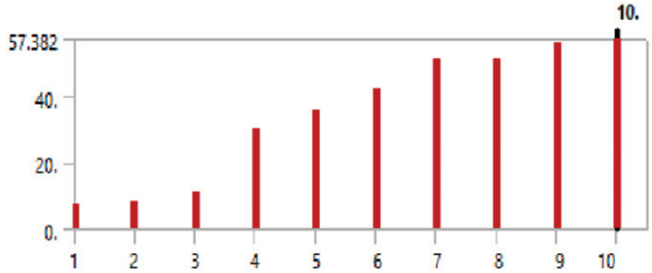


Figure 9: Total deformation for mode 1 frequency



Graphical view of the frequencies vs modes Case 1

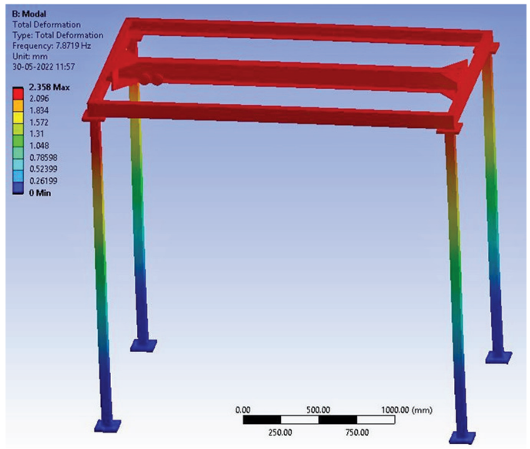


Figure 10: Total deformation for mode 2 frequency

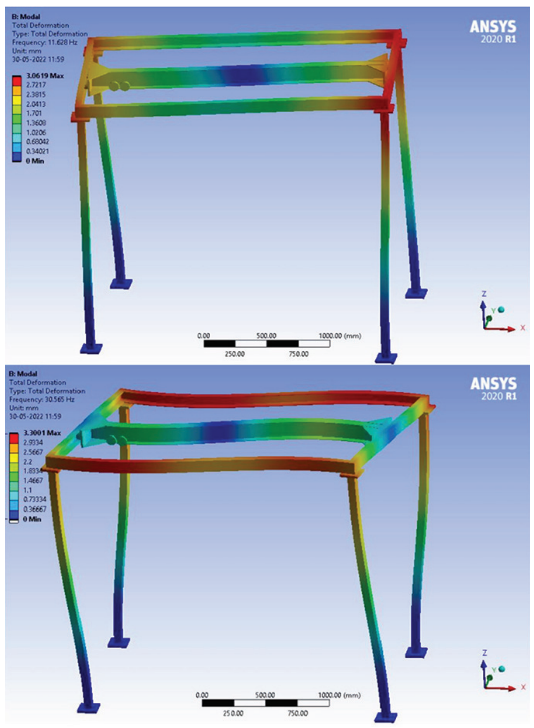


Figure 11: Total deformation for modes 3 and 4 frequency respectively

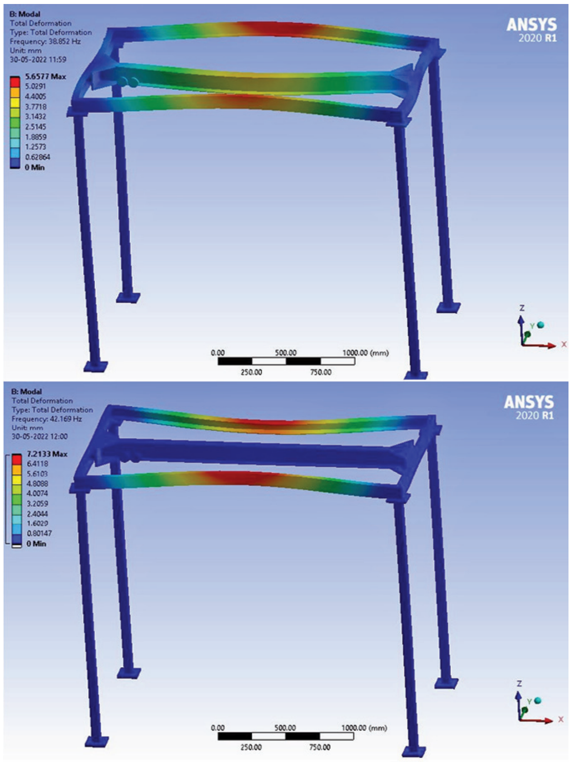


Figure 12: Total deformation for modes 5 and 6 frequency respectively

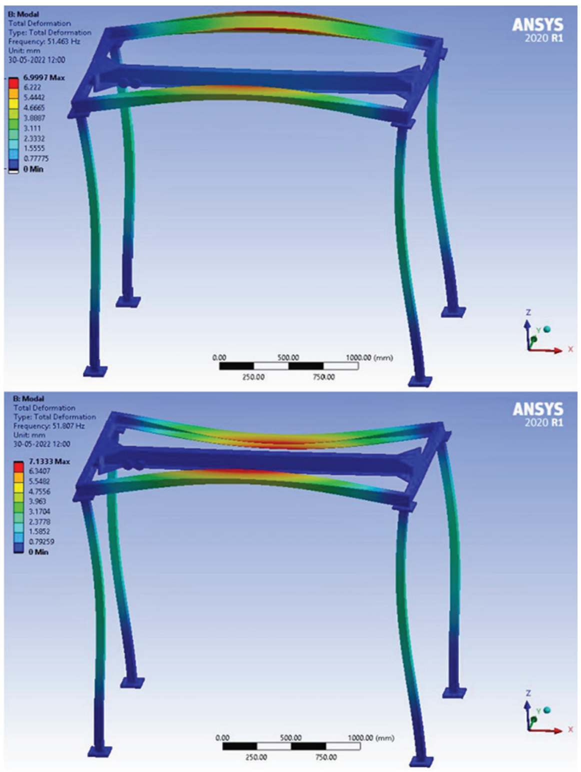


Figure 13: Total deformation for modes 7 and 8 frequency respectively

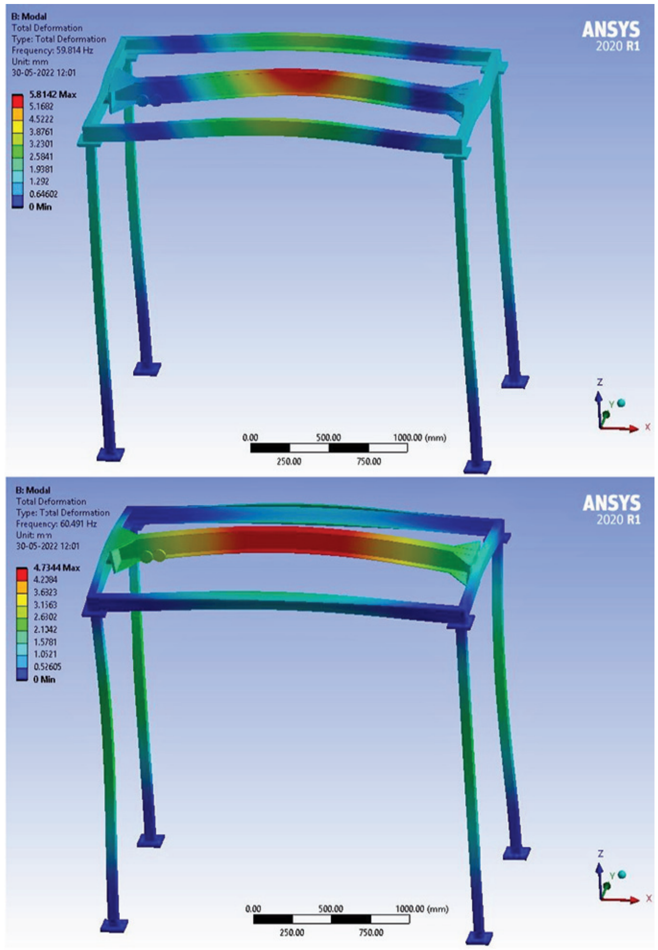


Figure 14: Total deformation for modes 9 and 10 frequency respectively

4.0 Conclusion

The above static and dynamic analysis concluded the results of total deformation, equivalent von-mises stress, and total deformation at different frequencies at different mode values. This was done for three cases where the load was acting at different positions on the model. Here the model meshed with the tetrahedron method. Here tetrahedron method was used because the total stresses and deformation values will be accurate to the original values to be obtained.

The total deformation of the model obtained for all 3 cases is 0.21mm, 0.32mm, and 0.413mm respectively. Since the deformation values are very less the model is satisfied and ready for production. The total von-mises stress of the model obtained for all 3 cases is 16.162Mpa, 25Mpa, and 22.21Mpa respectively.

The factor of safety = Ultimate tensile stress/allowable stress

- The ultimatete tensile stress of mild steel is 440Mpa
- Allowable stress obtained from analysis for all 3 cases is 16.162Mpa, 25Mpa, and 22.21Mpa respectively.

The factor of safety of all 3 cases obtained is 27, 17, and 20 respectively.

Since the safety factory is very high, the model satisfies the von-mises condition.

Aspect Ratio

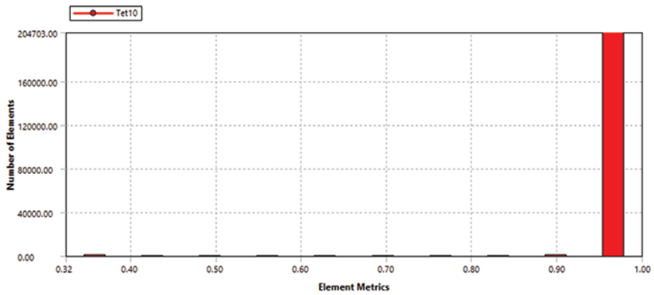


Figure 15: Aspect ratio from analysis

Skewness

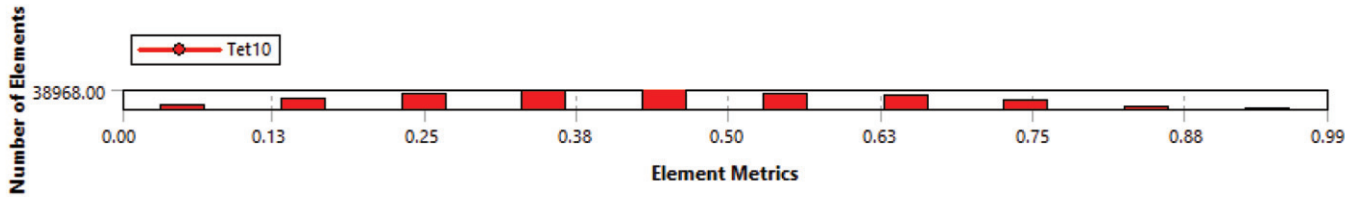


Figure 16: Skewness graph from analysis

Jacobian Ratio

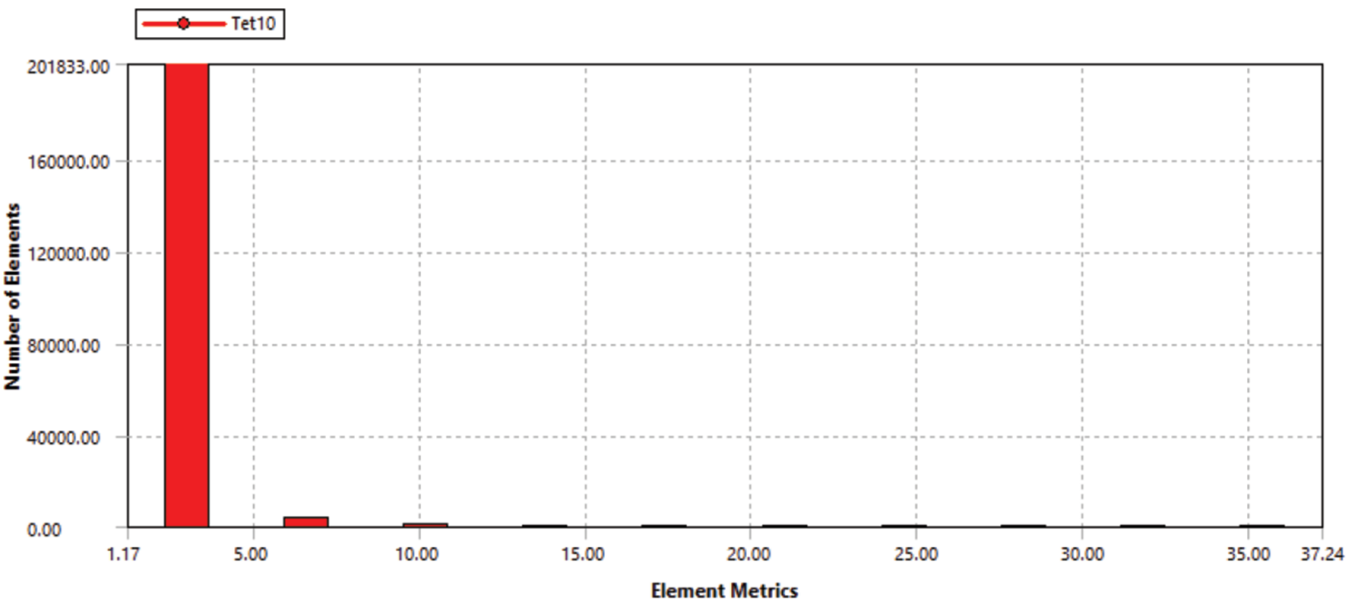


Figure 17: Jacobian ratio from analysis

References

[1] M Eric Johnson, Margaret L Brandeau, "Stochastic modeling for automated material handling system design and control", 330-350,1996.

[2] Benita M Beamon, "System reliability and congestion in a material handling system", 673-684, 1999.

[3] Andreas Bjornsson, Marie Jonsson, Kerstin Johansen, "Automated material handling in composite manufacturing using pick and place system ", 22-229, 2018.

[4] Harjo Baskoro, Harjanto Prabowo, Agung Trisetyarso, Achmad Nizar Hidayanto, "Design considerations for RFID based baggage handling system", 210-214, 2017.

[5] Sarawoot Chittratanawat, "An integrated approach for facility layout, location, and material handling system design", 683-706, 1999.

[6] Michael C Fu, Bharat K Kaku, "Minimizing work-in-process and material handling in the facilities layout problem", 29-36, 1997.

[7] Michael G. Kay Fitts, "Material Handling Equipment", Dept. of Industrial and Systems Engineering North Carolina State University.

[8] Vikas Gupta1, Rajesh Bansal, "A Review on Material Handling Equipment and Their Selection for Potential applications".

[9] Mohsen and Hassan, "A framework for selection of material handling equipment in manufacturing and logistics facilities" *Journal of Manufacturing Technology Management*, Vol.21 No. 2, pp. 246-268, 2010.

[10] B Mahadevan and T T Narendran, "Design of an automated guided vehicle-based material handling system for a flexible manufacturing system", *International Journal of Production Research*, Vol.28, 1990.