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FINITE ELEMENT ANALYSIS OF FORK IN A MODIFIED SCREWED MODEL IN FORKLIFT

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The goal of this study is to do a stress, strain and displacement analysis on an upgraded screwed model of fork lift. The forklift model was developed using Solidworks and through Solidworks simulation, the needed analysis of the specified parameters was also performed using the Finite Element method. The model was improved based on the standard original geometry of parts that were employed in terms of stress, strain, and displacement of the fork at crucial regions. The forks of the structural element were modeled as a cantilever beam with uniformly distributed load and the analysis was carried out using the usual Finite Element Analysis (FEA) method. Modifications to the meshing element size were used to improve the fork. The meshing element size ranges from 32 mm to 3 mm. When compared to analytical data, the outcomes of shrinking the element size yield better results in terms of stress, strain, and displacement.

1. Introduction

Forklifts with modifications are widely employed in industry to load and unload small and heavy industries from one site to another. After increasing their use for material delivery, these lifts are now used for vertical storage, saving even more space [1]. As a result, industry is expected to store materials more efficiently in warehouses. To reach larger heights, warehouses require a large number of manoeuvrable trucks. Since then, it has become the most important piece of warehouse equipment for both small and large businesses. The forklift manufacturing business had a manufacturing turnover of around $27 billion [2]. Electric forklifts are becoming increasingly popular, and they are powered by stored batteries. Indoor applications are best suited for these forklifts. Electric forklifts have a lower running cost than other models [3, 4].

Allwyn *et.al.,* [5] have done that design and development of mechanical forklift. Authors have concluded that the developed forklift equipment is compact in size and also it can be the alternative for the manual lifting. Many small-scale industries can afford this in low cost. Bozkurt *et.al.,* [6] have conducted analysis using finite element method and seen geometry improvements for specific structural parts with respect to stress distributions at critical region of a diesel forklift truck. Ahmed *et. al.,* [7] have investigated fixed end of deep cantilever beams. Authors have presented that numerical investigation solution in the form of graphs and concluded that discrepancy appears at the fixed end. Aktas [8] has conducted numerical investigation on cantilever beam subjected to point and distributed load. Author has listed results which are obtained through numerical formulas for different fiber directions and concluded that deflection angle at the free end increases from 0º to 90º for both the loading cases due to decreasing of stiffness. The design and multi-analysis of modular steel pallets that combine blocks and deck boards to generate various configurable configurations was the subject of this work. The performance of these pallets under transit (dynamic forklifting) and stationary (racking, stacking) situations was investigated by Authours using a combined numerical and experimental methodology. The authors concluded that 3D FEM models were effective in estimating stresses and deformations under various load circumstances [11].

The main objective of this project work is the design and development new model forklift and followed with following analysis. Those analyses are Stress, strain and deflection analysis of fork. The following chapters will focus on creating a new design of the fork based on the standard model forklift type with certain criteria, developing a CAD model, analytical stability calculation and performing stress analysis on the new design.

2. Materials and Methodology

The following major components are used in the forklift. Figure 1 (a) and (b) show that the schematics of the major components and exploded view in the CAD model. Figures 2 and 3 are the orthographic views of the fork lift.

1. Lead screw and nut: Normally, Lead screws are made with square threads because there is no loss in the power transmission ratio. So, these types of threads provide higher efficiency than other types of threads such as buttress thread, round thread and V- thread. The selected material is mild steel, and the nuts are made of high carbon steel.
2. Guide Column: The mast is a structural member that is located along with the guide column and it can be seen by the operator's vision. The guide column is mainly used for supporting the load applied on the fork and the load available on the tray and enclosing the assembly of other parts.
3. Mast or Fork: A Fork is used to lift, lower and position a load in the desired location.
4. Wheels: These are used to run the vehicle since it's being attached with a motor.

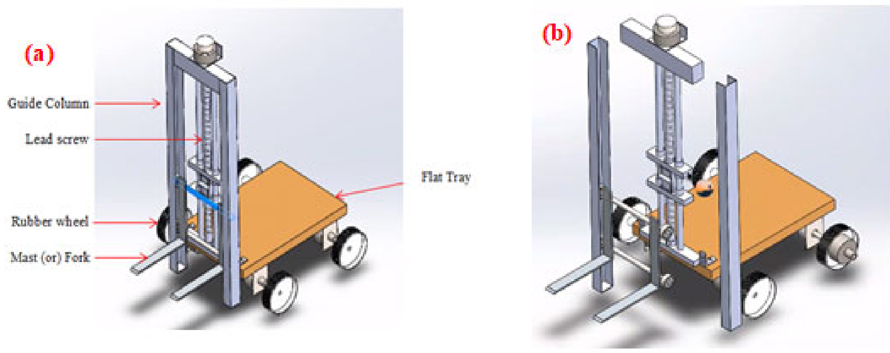

Figure 1. (a) Schematic of screwed model and (b) exploded view of a Fork lift

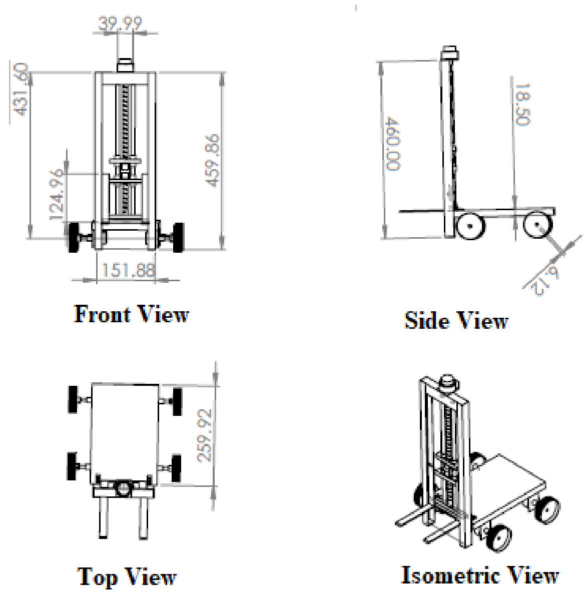

Figure 2. Orthographic and Isometric view of Fork lift (All dimensions are in mm)

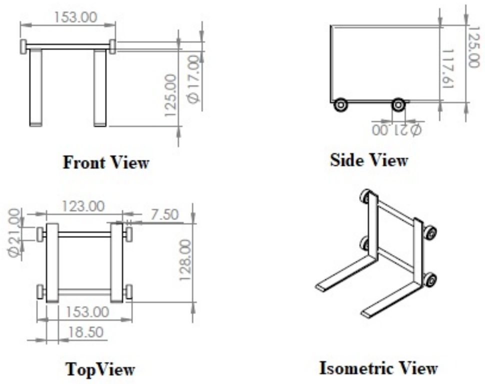

Figure 3. Orthographic and Isometric view of Fork (All dimensions are in mm)

2.1. *Analytical approach*

By considering that two forks are subjected to a uniformly distributed load of 20 N/m throughout the beam. The cross sectional dimensions of the fork are assumed to be 19 X 8 mm and the length of the beam is 125 mm. Mathematically,

Bending stress can be calculated by, $\sigma_b = M_b / Z$, N/mm^2 where M_b is maximum bending moment, N-mm and Z is the section modulus in mm^2. The Final result of Bending stress, strain and displacement is 385 MPa, 0.00183 and 3.995 mm, respectively.

2.2. *FEM approach*

The design concept and proportions for the fork were derived using an analytical method in previous chapters. Solidworks simulation is used to verify the analytical stress, strain, and displacement calculations. Suryoputro *et. al.,* [10] have conducted FME Analysis for Forklifts. Normal FMEA and Fuzzy FMEA were used to apply the concept. According to the authors, Fork received a moderate fuzzy Risk Priority Number (RPN) with a value of 538. The authors have concluded that severity of failure to the mast in the forklift occurs frequently. Hence, the mast or fork is the one which is loaded most, and it is taken for the FEA analysis. Tables 1 and 2 contain the material properties and mechanical properties of the fork.

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The finite element method is used for structural analysis, as seen in Figure 4. A rectangular - sectioned physical object has been modeled and partitioned into small elements. The preprocessor program then creates the finite element solid mesh. For the case of a cantilever beam with uniformly distributed load, the model is imposed with boundary conditions based on the mechanical properties listed in Table 2. The model is now run for post-processing by making the appropriate modifications to the various element size and selection. Finally, solutions for stress, strain and displacement of the rectangular section have been found.

Table 1. Material Properties of Fork [9]

Material	C %	Mn %	Si %	S %	Ph %
Mild steel	0.2 to 0.3	0.7 to 0.9	0.4	0.04	0.04

Table 2. Mechanical Properties of Fork [9]

Tensile yield strength (N/mm^2)	Compressive Yield strength (N/mm^2)	Young's Modulus (N/mm^2)	Poisson's Ratio	Density (kg/mm^3)
400	250	210×10^3	0.3	7800

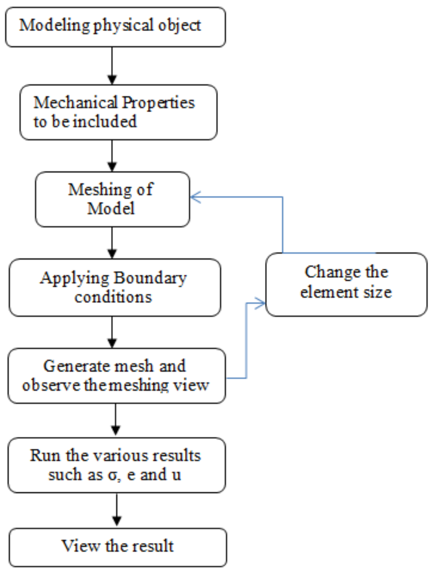

Figure 4. Structural analysis through FEM approach.

3. Results and Discussion

The main goal of this research is to determine the stress, strain and displacement values. The meshing model and final solution of stress, strain, and displacement of a forklift are shown in Figures 5 and 6, with element sizes of range between 3 mm and 32 mm respectively. The solutions for vaious element sizes ranging from 2 to 32 mm are given in Table 3. Figure 7's results plot demonstrates that the overall solutions for tiny element size in all three parameters are much higher. Almost all characteristics remain same, although element size is increased from 9% to 20%. As a result, results for small element sizes are taken and compared to the analytical solution. However, because all of the material follows Hooke's rule, the analytical answer is less than the simulation results.

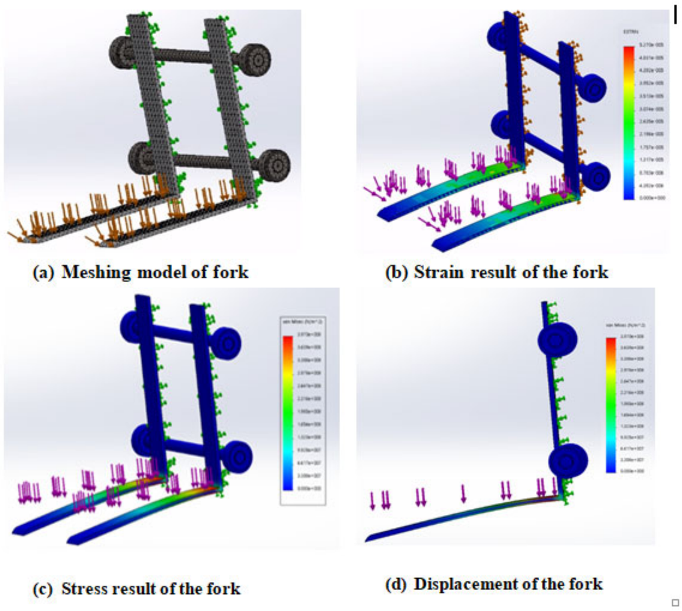

Figure 5. Meshing model and Analysis results of Fork for element size 3 mm.

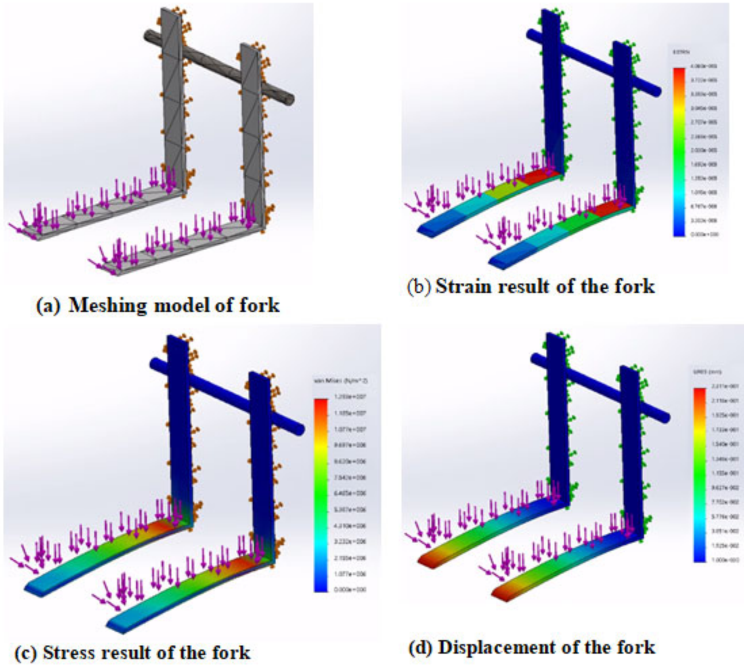

Figure 6. Meshing model and Analysis results of Fork for element size 32 mm.

Table 3: Data of Stress, Strain and displacement analysis of Fork Model using various element sizes.

Element Name	Element size L (mm)	Von-Misses Stresses (N/mm^2)		Displacement		Strain	
		Min	Max (x10^6)	Min	Max	Min	Max (x10^{-5})
Solid Triangular Mesh	3	0	397.1	0	3.803	0	5.2500
	4	0	163.4	0	2.495	0	4.9700
	5	0	157.2	0	2.461	0	4.5960
	15	0	134.5	0	2.311	0	4.1270
	25	0	131.5	0	2.348	0	4.0600
	32	0	129.3	0	2.281	0	3.7370

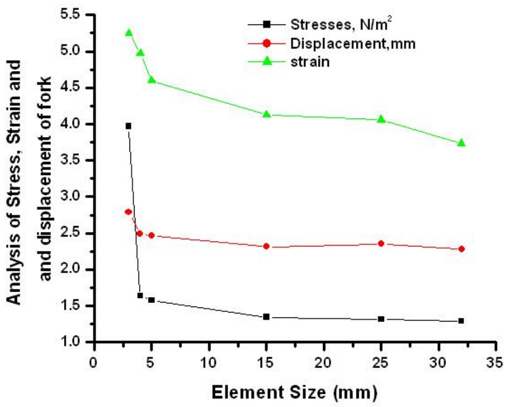

Figure 7. Plotted graph between Element size and stress, strain and displacement at the fixed end of fork

4. Conclusion

In this work, FEA was used to evaluate the stress, strain, and displacement analysis of a specific component. Small element sizes are utilized to analyse for comparison of data in order to acquire exact results that are close/better than the analytical results, as can be seen. It was found that the design was sufficiently trustworthy by comparing simulation results to the required size of the produced model. While the forklift is in operation, no detrimental impacts are expected based on the results of deformation under these loads.

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