Impact of shifting load centres on stability of the forklift

Pratyush Deshmukh
Amity University Mumbai
Email: pdeshmukh423@gmail.com

Gunchita Kaur Wadhwa
Amity University Mumbai
Email:gkwadhwa@mum.amity.edu

Abstract:

This study discusses how to design a system to establish the stability of a forklift fork working with different weights using designing and simulation software. The stresses which appear in the lifting installation of a fork-lift truck at loading-unloading operations are investigated for given input data like load carrying capacity of fork, the effects of various loads on different positions of the fork in terms of stresses and then compare calculated Stresses with material allowable stresses (yield stress/F.O.S). This paper focuses on the significance of Load Centre when subjected to loading at different positions.

Keywords: Forklift, load centre

1. Introduction

Forklift is an industrial power truck used for lifting and transport materials. Through the steel fork under the load, the lifting and transportation have been done. At present, different kinds of forklift are many. The load carrying capacity of a forklift varies from 500 to 10000 Kg. The most important part of a forklift is the fork which is responsible for carrying the load is forklift fork. They're the reason the machine is called a forklift so they are crucial to safe operation. The cantilevered arms attached to the load carriage that engage the load. There are 3 types of fork mounting which are:-

Standard hook type:

This is the most common way of connecting forks to the lift-truck world-wide.

Pin/Shaft type: Pin-Type forks are guided on a shaft. The dimensions are not standardized. Pin-type forks are individually designed to customer's requirement. Mostly pin-type forks are used for larger lift trucks or for construction machines.

Bolt on type: Forks which are fixed to the lift truck or to an attachment by screws. Drill patterns are not standardized and may vary depending on the manufacturer of the lift truck or the attachment. As a result of the drill hole and the resulting fatigue notch, the capacity of screw fastened forks is lower than the capacity of standard forks with a comparable cross-section. This paper further discusses how to design a system to establish the stability of a forklift fork working with different weights using designing and simulation software. This analysis can be used by forklift fork manufacturing industries. This can be also used by industries using forklift truck for shifting goods.

2. Review of Literature

The stability of the forklift under loading still seems to be one of the biggest concerns till date. As a consequence there are a large number of accidents that lead to the loss of loads, damage of forklifts and injury to operators. The need for solving this problem of forklift stability occurs mainly in a number of different circumstances such as: when the forklift is moving on uneven surfaces, while turning on a tight radius, accelerating and braking, at the beginning and end of lifting or lowering, manoeuvring the forklift, when lifting a tall stack loaded on the forks, when unloading, when the angle of the chassis of the forklift to the load is a maximum, when the forklift is angled on an adverse camber and when the forklift is braking suddenly from high speed.

The stability of wheeled lifting machines is empirically ascertained by manufacturer as part of the certification process. During certification of every model of wheeled lifting machines the transportation and lifting characteristics of the device are tested and defined and the limits of the operational capabilities and the boundary conditions of use are measured. Whilst the parameters of the forklift performance can be tested and specified, the characteristics of the loads are variable and cannot be completely defined or tested; they can be very different from the standard load used in certification. The solution to this problem is traditionally associated with the measurement of coefficient of longitudinal and lateral stability in motion and stacking of the load [1]. With the AGVs coming into picture, one of the tools utilised for the same seems to be the Forklift. It’s extensively used for various works involving stacking, loading / unloading etc. Nowadays the storage system needs to be modified as the space availability constraints have lead to Hi Tech storage spaces occupying less land and stacking items in layers [8].

In this system the steering and the seating arrangements of the driver are in such a position that strong vibrations can be felt.

3. Methodology

3.1. Dimensions and calculations of existing fork

The forklift fork is subjected to loading at different positions and thus has load centre that changes. This load centre moves forward and rearward as the load is applied forward and rearwards of the original load centre. The stability of a fork can be affected by such factors as:

- Size, weight and position of load.
- Forward and rearward shifting load centre.
- Exceeding the load carrying capacity.

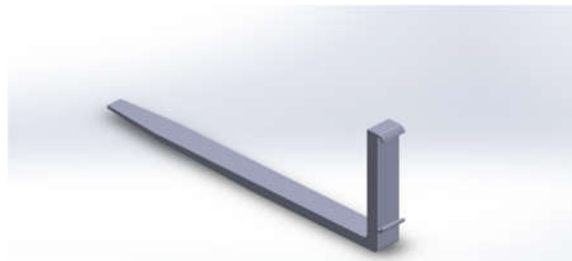


Figure 1: 3 D model of forklift fork

The above figure shows solid model of forklift fork. Solid works is a solid modelling software used by design engineers world wide for 3D modelling of a components. The designing dimensioning and modelling of the fork was executed on theSolidworks.

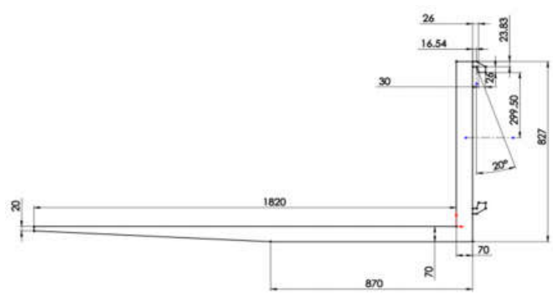


Figure 2: Dimensions of forklift fork.

3.2. Material Selection

Materials commonly used to manufacture forks are alloy steels. Some of the best suited materials used for analysis are

- AISI 4340 Alloy Steel
- AISI 1045 Steel

- AISI 1060 Carbon Steel
- AISI A514 Grade B Alloy Steel
- HSLA A572 Grade

After the comparison of various materials by weighted residual material selection method on the basis of desired properties AISI A514 Grade B Alloy Steel is taken as the most

Sr No.	Material	Yield Stress	Allowable Stress
	Units	MPa	MPa
1	AISI A514 Grade B Alloy Steel	690	230
2	AISI 1060 Carbon Steel	485	162
3	AISI 4340 Alloy Steel	470	157

preferred material.

Boundary Conditions and Calculation

Factor of Safety = 3

Fork is fixed at the mounting

Loading Condition Study

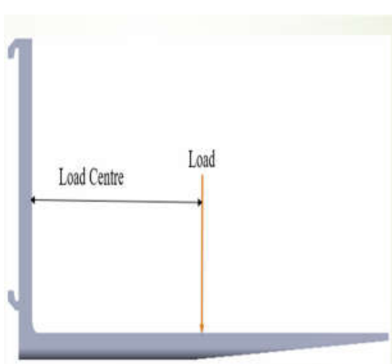
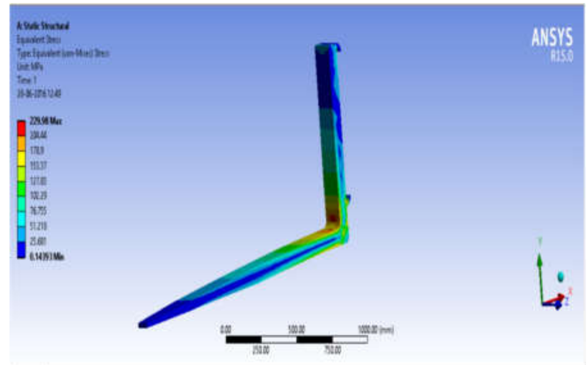


Figure 3: Loading condition

Fork carries maximum load when load acts at the load centre of the fork.



3.3. Data analysis on Ansys Workbench

Figure 4: Von Mises Stress on AISI A514 Grade B Alloy Steel

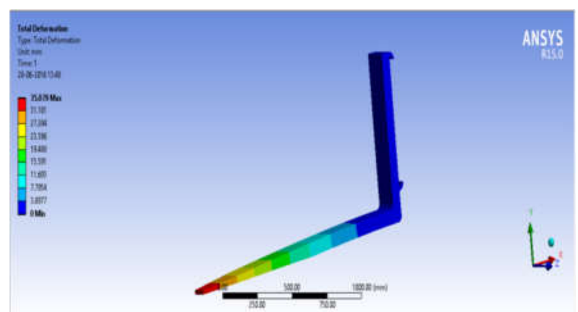


Figure 5: Deflection on AISI A514 Grade B Alloy Steel

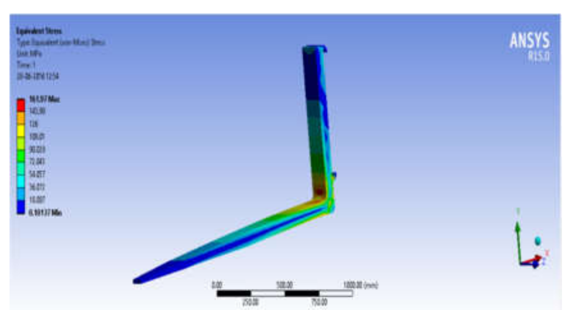


Figure 6: Von Mises Stress on AISI 1060 Carbon Steel

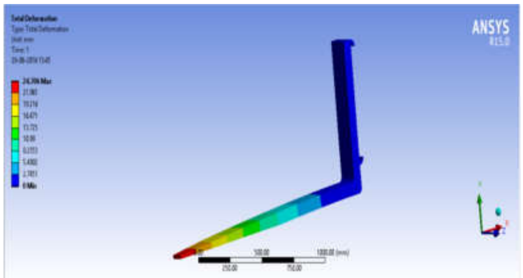


Figure 7: Deflection on AISI 1060 Carbon Steel

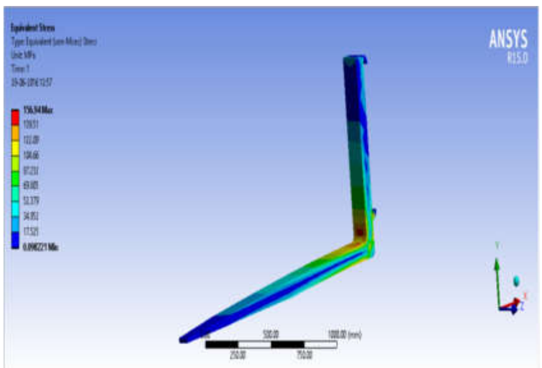


Figure 8: Von Mises Stress on AISI 4340 Alloy Steel

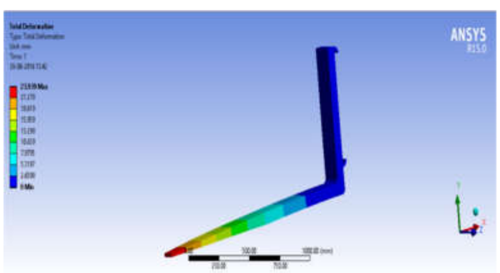


Figure 9: Deflection on AISI 4340 Alloy Steel

3.4 Significance of Load Centre when subjected to loading at different positions.

As the load centre increases the load carrying capacity of the fork decreases which can be calculated be the formula:-

$$New\ load\ carrying\ cpacity = \frac{Load\ carrying\ capacity * Load\ Center}{New\ load\ center}$$

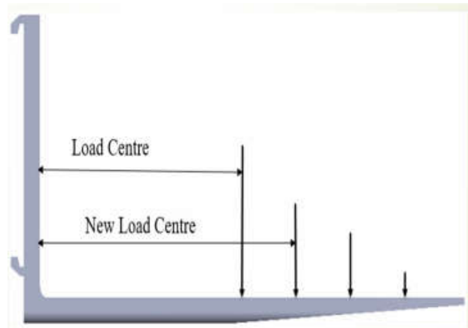


Figure 10: Shifting load centres

4. Data Analysis, Results and Interpretation

4.1. Simulation Result Chart

Table 3: Simulation Result Chart

Sr No.	Material	Yield Stress	Allowable Stress	Applied Load	Von Mises Stress	Deflection
Units		MPa	MPa	Newton	MPa	Mm
1	AISI A514 Grade B Alloy Steel	690	230	28575	229.98	35.079
2	AISI 1060 Carbon Steel	485	162	20125	161.97	24.706
3	AISI 4340 Alloy Steel	470	157	19500	156.94	23.939

4.2. Loading at different load centres

4.2.1 AISI A514 Grade B Alloy Steel loading at different Load Centres

Load Centre: 910 mm

Load Carrying Capacity: 2913Kg

Table 4: AISI A514 Grade B Alloy Steel Loading at different Load Centres

Sr No.	New Load Center	New Load Carrying Capacity
Units	Mm	Kg
1	1010	2624.584158
2	1110	2388.135135
3	1210	2190.768595
4	1310	2023.534351
5	1410	1880.021277

4.2.2 AISI 1060 Carbon Steel Loading at different Load Centres

Load Centre: 910 mm

Load Carrying Capacity: 2051Kg

Table 5: AISI 1060 Carbon Steel Loading at different Load Centres

Sr No.	New Load Center	New Load Carrying Capacity
Units	Mm	Kg
1	1010	1847.930693
2	1110	1681.45045
3	1210	1542.487603
4	1310	1424.740458
5	1410	1323.695035

4.2.3 AISI 4340 Alloy Steel loading at different Load Centres

Load Centre: 910 mm

Load Carrying Capacity: 1988Kg

Table6: AISI 4340 Alloy Steel Loading at different Load Centres

Sr No.	New Load Center	New Load Carrying Capacity
Units	Mm	Kg
1	1010	1791.168317
2	1110	1629.801802
3	1210	1495.107438
4	1310	1380.977099
5	1410	1283.035461

5. Conclusions

Based on the results AISI 4340 Alloy Steel is an ideal material to manufacture forklift forks as it is given first preference by weighted residual material. It also has the highest weight carrying capacity as determined by the simulation results. The weight carrying capacity and strength of the fork depends on the material used for manufacturing whereas the effect of shifting load centres is independent of material properties and only on dimensions. Standard hook type fork is used for analysis in this project because of standard dimensions however Pin/Shaft type forks can also be used for specialised and heavy operations.

6. Limitations of the project

Forks can only be manufactured by using high strength alloy steels which are quiet expensive and hence increase the cost. In no way the effect of shifting load centres can be controlled or minimised. In case of bolt on type forks, drill patterns are not available in standard sizes and can vary. Therefore the drill hole and the resulting fatigue notch, the capacity of screw fastened forks is lower than the capacity of standard forks with a comparable cross-section. Thus use of bolt on type fork is not advised.

Bibliography

1. I.I. Boyko, S.P. Cherednichenko «Transport-freight systems and warehouses: educational manual»/ . Rostov -Don/ Phoenix, 2007 p.155-161.
2. Carina Rislund, HilleviHemphälä, Gert-Åke Hansson c, IstvanBalogh (2013), “Evaluation of three principles for forklift steering Effects on physical Workload”, International Journal of Industrial Ergonomics, Vol. 43.
3. Ehlanda A, Williams M S and Blakeborough A (2010), “Dynamic load model for fork-lift trucks”, Engineering Structures, Vol. 32, pp. 2693–2701.
4. George Pantazopoulos, Athanasios Vazdirvanidis, Andreas Rikos and AnagnostisToulfatzis (2014), “Analysis of abnormal fatigue failure of forklift forks”, Case Studies in Engineering Failure Analysis, Vol. 2, pp. 9–14.
5. Jan-Florian Hoenghoff, Andreas Jungk, Werner Knop, and LudgerOvermeyer (2011), “Using 3D Field Simulation for Evaluating UHF RFID Systems on Forklift Trucks”, IEEE Transactions On Antennas And Propagation, Vol. 59, No. 2, February 2011.
6. Juan M Massone and Roberto E Boeri (2010), “Failure of forklift forks”, Engineering Failure Analysis, Vol. 17, pp. 1062–1068.
7. NolimoSolman K (2002), “Analysis of interaction quality in human–machine systems applications for forklifts”, Applied Ergonomics, Vol. 33, pp. 155–166.
8. Souvik Das, GoutamMukhopadhyay and Sandip Bhattacharyya (2015), “Failure analysis of axle shaft of a fork lift”, Case Studies in Engineering Failure Analysis, Vol. 3.
9. Timothy R, Driscoll N, James E Harrison, Clare Bradley, Rachel S Newson (2008), “The Role of Design Issues in Work-Related Fatal Injury in Australia”, Journal of Safety Research, Vol. 39, pp. 209 – 214.
10. Tim Horberrya Ã, Tore J Larssona, Ian Johnstona and John Lambert (2004), “Forklift safety trafc engineering and intelligent transport systems a case study”, Applied Ergonomics, Vol. 35, pp. 575–581.