

## Summary

Mitsubishi Caterpillar Forklift Europe BV situated in Almere, the Netherlands is a manufacturer of Mitsubishi and Caterpillar Forklift trucks. Electric powered and internal combustion forklift trucks are manufactured at the factory in Almere for the world market.

A 2.0 ton capacity mast is currently assembled on the small electric forklift trucks with lifting capacities ranging from 1.0 to 1.6 tons. Because the mast is too strong for the intended loads it looks too big and out of place on the forklift truck. This is further emphasized when compared to other forklift manufacturers which do have a mast that fit the contours of the small forklift truck. The assignment is to design a mast suited for the small capacity electric forklift trucks that is comparable in size to the competitor's low capacity forklift masts.

The following boundary conditions were applicable for the assignment:

- Design the new forklift mast using the 4.8 meter Triplex mast and 4.1 Duplex mast as templates.
- Truck side modifications which lead to a redesign of the truck frame are not allowed.
- The mast must be able to operate in temperatures between -20 and 40 degrees Centigrade.
- The new mast design must pass the MHI endurance test.
- It must be possible to manufacture the mast in-house at MCFE.
- The return on investment period must not exceed 2 years.

The following design criteria were formulated for the assignment:

- When handling the rated load of 1.6 tons the occurring stresses in the mast must not exceed the allowable values specified by the 13001 standard.
- The mast must endure 120000 lifting cycles before failure with the rated load of 1.6 tons.
- The buckling load must be at least 3 times higher than the highest occurring dynamic load when handling the rated load of 1.6 tons.
- The mast must be more in scale with the small electric forklift trucks while still satisfying the constructional requirements.
- The operator visibility through the mast must at least be equal to the visibility through the current mast.
- The cost reduction target is €70.

Because there are no guidelines for the design of forklift masts, it was investigated if the 13001 and 2019 standards are applicable to forklift mast design. This was done by creating a finite element model of the current mast and performing a Finite Element Analysis according to conditions specified in the 13001 and 2019 standards. It was concluded that the 13001 and 2019 standards are applicable for the design of forklift masts

After the investigation several possible improvements were generated which could improve the mast design. These improvements were assessed for feasibility using the boundary conditions formulated for the assignment. It was concluded that the optimal design according to the boundary conditions was an improved current mast design which uses smaller mast profiles, smaller cross members, smaller hydraulic lift cylinders and smaller lifting chains. The 13001 and 2019 standards were used to design the improved current mast design.

The improved current mast design is then assessed according to the design criteria and a cost reduction estimation is made for the new design.

The main conclusions of the assignment are:

- The constructional requirements specified by the 13001 and 2019 standards can be applied for the design of forklift masts.
- The forklift mast is relatively low stressed with the highest stresses occurring in the contact area between the inner mast profiles and the lift bracket.

- The hydraulic lift cylinders determine the buckling stability of the mast.
- According to the boundary conditions and design criteria the most optimal design for this assignment is an improved current mast design.
- The improved current mast design conforms to the constructional requirements specified by the 13001 and 2019 standards.
- The smaller dimensions of the improved current mast design result in it being more in scale with the small electric forklift trucks than the current mast.
- The operator visibility of the improved current mast design is improved, the viewing width is increased by 12 [mm]
- An improved current mast design for forklift trucks with capacities between 1.0 and 1.6 tons is financially attractive. The cost reduction of the new mast design is equal to €114 which exceeds the target of €70.

Recommendations for improvements and future research are:

- For future design purposes it is recommended to obtain load data by means of testing
- To improve operator visibility and visual appearance of the mast it is recommended to investigate alternatives for hydraulic hose routing and finishing such as a hydraulic hose option.
- It is recommended that the suggested improvements which were unsuitable for this assignment be included in future forklift truck designs.
- Application of higher strength steel grades for the mast construction is recommended because this will lead to a reduction of weight and costs and an increase in lifting capacity. This is interesting for mast with high lifting heights.