사이드 로딩 지게차 트레일러의 새로운 컨셉 디자인 분석
Analysis of New Concept Design of a Side-Loading Forklift Trailer

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1. Introduction

In this article, new concept for the design of side-loading forklift, the proposed analysis and design optimization approach are reported. Unlike conventional and existing designs the new concept includes a retractable fork that is also can be adjusted sideways to services various load (car) sizes and flatbed load platform.

2. The concept design

Figure 1 shows the concept design of the side-loading forklift trailer. Particularly, this side-loading forklift trailer is designed to lift cars (load) by gripping the tires using two pairs of forks. These forks are adjustable sideways so that cars of varied sizes can be serviced. The target maximum load capacity is 3 tons. The loading scenario (grab-and-lift load) is considered to have the most effect to the structural performance of the trailer. To evaluate the structural performance (stresses, displacements, fatigue safety factor, etc...), the mentioned scenario can be simulated using computer software based on the finite element method (FEM). Once the baseline structural performance is established, parametric study or design optimization method such as size and shape optimization can be carried out to ensure optimal outcome – economically and performance-wise.

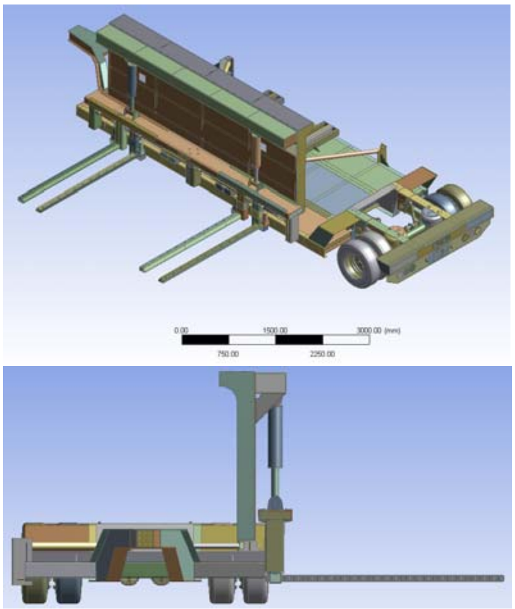

Fig. 1. Concept design of side-loading forklift

3. Analysis and simulation

Preliminary analysis of the concept design revealed unfavorable results. Like for instance, the maximum tip displacement of the fork was close to 150mm and stresses were over the yield limit. The 150-mm displacement of the fork is considered too large for the current design. One of the design objectives then is to redesign the fork such that the tip displacement is reduced to acceptable values. To do this the fork is isolated for parametric study. ANSYS Workbench [1] is used to do the task and it offers a very convenient way of setting-up the parametric study. Figure 2 shows the final fork section design obtained based on the results of parametric study and spatial constraints. Spatial constraints include clearances to the ground and fork block among others.

After the parametric study of the fork, the chosen design is integrated back to the full assembly (Fig. 3) and the analysis is Geometric model simplification [2, 3], is implemented to reduce problem complexity and size so that solution is ensured and obtained quickly.

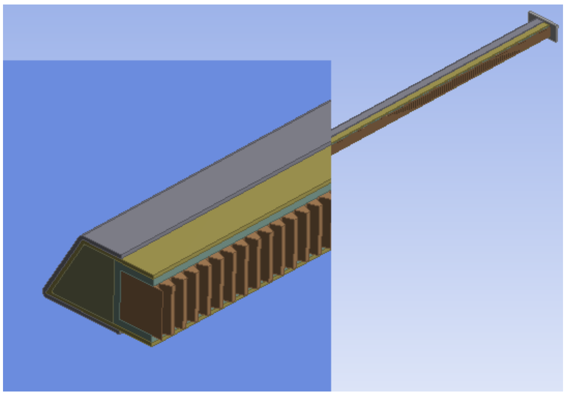

Fig. 2. Fork section design obtained from parametric study

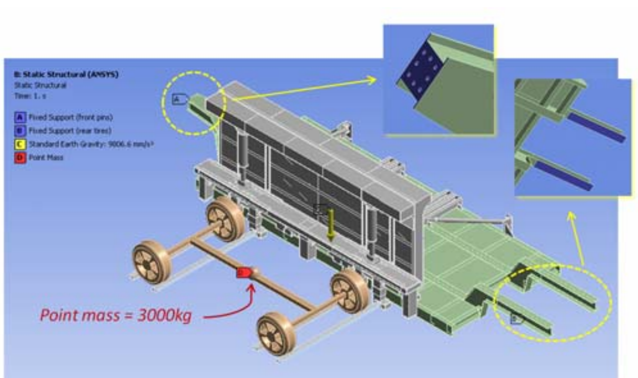

Fig. 3. Full 3D-model of the simulated side-lifting trailer

Static structural analysis is considered in the simulation. Considerations and assumptions in the simulation are as follows (refer to Fig. 3):

-The load (a car) is modeled as rigid body (non-deformable) since the analysis is focused mainly on the forklift trailer structure itself. To closely account for the physics of the load and the tire contact surfaces, tire size [4,5] and tire location are based on actual dimensions of Hyundai Santa Fe [6].

-The self weight of the forklift trailer is considered and defined by specifying the standard gravity. With the gravity given, the weight of the car is imposed as point mass located at the center of gravity of the car model.

-Course mesh using high-order solids elements are used to reduce problem size while giving fairly accurate results. Figure 4 shows the mesh quality used in the simulation.

-Contact conditions: Pins/axles are allowed to slide but cannot separate from other contacting parts. In ANSYS Workbench it is set as "No Separation" contact. Forks are allowed to slide without separation from other contacting parts ("No Separation"). Frictional contact is not simulated due to nonlinearity and hard-to-converge solution.

-Details of the rear tires and the suspension system are not included. Instead, simplified support region is specified.

-Material properties are shown in Table 1.

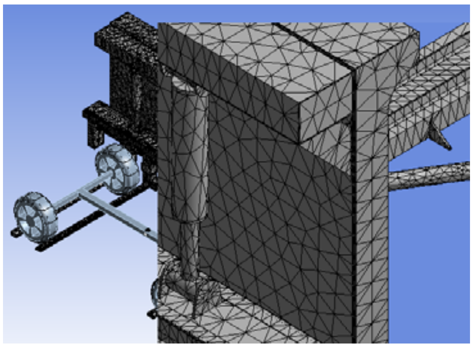

Fig. 4. Mesh of the side-loading forklift trailer model

Table 1. Material data

Components		Weight
Forklift : ATOS80		2066.7 kg
Young's modulus	228.88 GPa	
Poisson's ratio	0.3	
Yield strength	708.96 MPa	
Ultimate strength	781 MPa	
Rack and pinion: SM45C		
Young's modulus	210 GPa	
Poisson's ratio	0.3	
Yield strength	373 MPa	
Ultimate strength	540 MPa	
Trailer: SS		1477.1 kg
Young's modulus	200 GPa	
Poisson's ratio	0.3	
Yield strength	250 MPa	
Ultimate strength	460 MPa	

4. Results and discussions

Figure 5 illustrates the stress distribution within the assembly. It is notable that the maximum stress (468MPa) occurs at the filleted region and appears to be localized. Away from this region the material has infinite life (10^6 cycles). The remedy to this can be done by exploring various sizes of the fillet such that stress concentration is reduced. With ANSYS Workbench this is can be easily done with parametric study approach.

The chosen fork section design exhibited a roughly 50% reduction of tip displacement. In fact, an isolated analysis of the fork revealed around 60mm tip displacement. This means that the additional 57-mm is imposed by the displacement of the trailer itself. It was observed that the major contributor to the 57-mm additional fork displacement was the sub-assembly supporting the forklift. Further design optimization of this sub-assembly using the previously mentioned approaches maybe carried out to improve the performance.

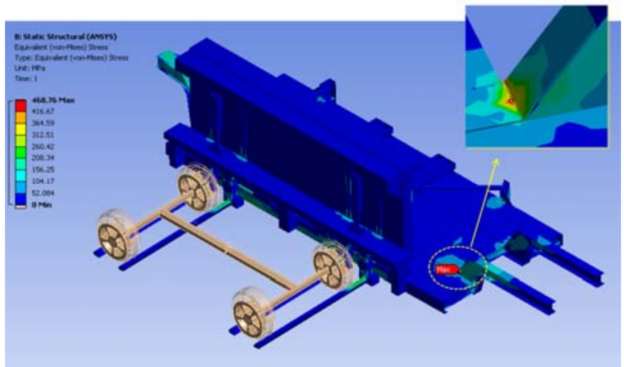

Fig. 5. Stress distribution within the side-lifting forklift trailer

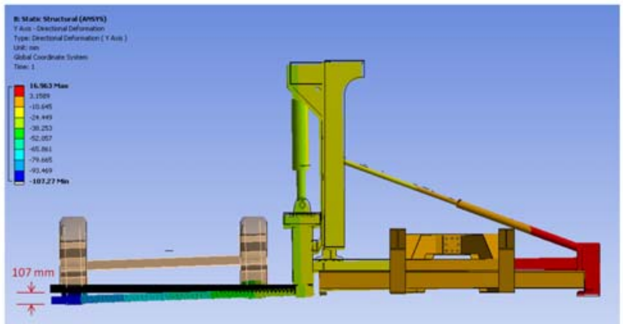

Fig. 6. Deformation of the side-lifting forklift trailer

Table 2. Results summary

	Self weight	No self weight
Maximum stress	468.76 MPa	343.2 MPa
Max. vertical displacement	107.27 mm	87.376 mm
Min. fatigue factor of safety	0.184	0.238
Minimum fatigue life cycles to failure	1706 cycles	2000 cycles

Conclusions

Preliminary static analysis of the new concept design of side-lifting forklift trailer is performed using simplified model and parametric study approach for design optimization. To obtain more improved structural performance, future work has to be focused on design optimization possibly using alternative approach such as size and shape optimization.

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