Multi-body Dynamic Analysis for Optimizing Automated Lift Frame in Garbage Trucks

Rajesh Kandula[1], Chinnababu Anima[2], Vijayakumar Vaka[3]

[1]Master of Technology in Design for Manufacturing at JNTU, Hyderabad, India

[2]Master of Technology in Mechanical Engineering at IITM, Chennai, India

[3]Master of Technology in Mechanical Engineering at National Institute of Technology, Calicut, India

Abstract: ***Automated lifts are integral components of modern garbage trucks, significantly improving efficiency and worker safety. Accurately modeling and simulating their dynamic kinematic behavior is crucial for design optimization, performance evaluation, and control system development. This paper presents a case study that analyzes a dynamic kinematic simulation framework for an automated lift using rigid and flexible body kinematic simulation tools to identify potential structural weaknesses of the structure and improve design.***

Keywords: Automated lift, garbage truck, Finite Element Analysis (FEA), Kinematic Simulation, optimization

1. Introduction

With increasing urbanization and waste generation in India, efficient and safe waste collection has become crucial. The waste management systems of the country are overwhelmed by the increasing volume of waste produced by expanding urban areas. There is a critical need for more efficient methods and processes to manage this waste effectively (1–3).

The automated lift system is a process where a mechanical arm on a garbage truck lift and empties household waste into the truck. This method offers several advantages, including better safety for workers, higher efficiency in waste collection, and improved ergonomic design. However, analyzing and optimizing the design and performance of these systems is crucial for maximizing efficiency, minimizing operational costs, and ensuring long-term durability. In recent times, the realm of engineering design and performance analysis of mechanical systems has witnessed a significant shift towards the use of virtual prototyping technology. These innovative tools, representing a new approach to design methodology, have gained increasing popularity due to its effectiveness and efficiency in the engineering domain (4). Figure 1 shows the simplified version of the automated lift where the C-Frame is mounted on the truck. Through hydraulic cylinders, the frames lift the waste bin and dump in into the truck. A case study is presented in this report to analyze and optimize the C-frame of the automated lift.

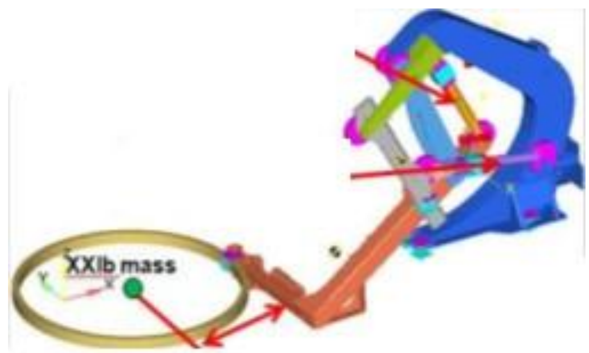

Figure 1: Automated Lift assembly

2. Software Tools and Simulation Workflow:

The multibody dynamic simulation can be implemented using Motion Solve. This tool provides libraries of rigid body elements, joint constraints, and force models, simplifying the modeling process. Simulation workflow is shown below.

- Model creation: Importing the lift geometry, defining joint types and properties, assigning mass and inertia values, and specifying actuator and environmental forces.
- Parameterization: Defining initial conditions, motion constraints, and simulation parameters like time step and solver settings.
- Simulation execution: Running the simulation and analyzing the results, including joint angles, velocities, accelerations, and forces acting on the system.
- Validation and analysis: validation of this model is not part of this study.

3. Multibody Dynamic Kinematic Modeling:

The multibody dynamic (MBD) kinematic approach treats the lift as a collection of interconnected rigid bodies with defined mass, inertia, and joint connections. This allows for the analysis of complex motions, including translations, rotations, and deformations, under the influence of various forces and torques. In MBD simulations, bodies can be rigid or flexible, Rigid bodies cannot undergo deformation flex bodies can undergo deformation (5). In this study, C-frame is modeled as a flex body, and all other components are modeled with rigid bodies.

Lift Kinematics:

Geometric Modeling: The lift's geometry is accurately modeled using 3D CAD software. This includes the arm segments, joints, actuators, and linkages, with their precise dimensions and relative positions defined. C-frame is modeled as flex body shown in Figure 2. All other parts are modeled as rigid bodies.

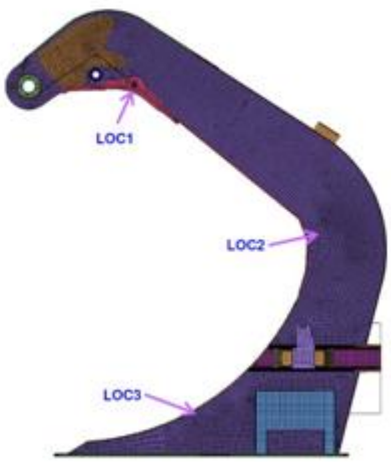

Figure 2: C-Frame with Focused area locations

Joint Types: The different types of joints in the lift are identified, such as revolute joints for rotation and translation joints. Each joint is assigned appropriate degrees of freedom and motion constraints. Figure 1 shows the Motion solve assembly model with joints.

Dynamic Modeling:

- Mass and Inertia: The mass and inertia of each lift component are determined using material properties and geometric data. These values are crucial for calculating the forces and torques acting on the system.
- Actuator Forces: The forces generated by the hydraulic cylinders or electric motors actuating the lift joints are modeled using force-displacement or torque-angle relationships. These relationships can be based on manufacturer specifications or experimental data.

Boundary conditions:

Load Case-1: - Near-side bin: Lifting and maneuvering a bin adjacent to the truck requires minimal travel and ensures stable handling.

Load Case -2: - Near-side bin with dump: Adding the dumping action necessitates precise positioning and control to align the bin with the truck opening.

Load Case -3: - Far-side bin: Extending the lift's reach to access a distant bin introduces additional complexity in handling and stabilization.

Load Case -4: - Far-side bin with dump: Combining distance and dumping demands advanced control algorithms to navigate and precisely position the bin for emptying.

4. Results and Discussion

The kinematic simulation of the automated lift is conducted using Altair's Motion Solve tool. In this simulation, the C-frame is modeled as a flexible body, while all other components are treated as rigid bodies. This approach led to the identification of three critical regions in the lift's operation, which are clearly marked and detailed in Figure 2.

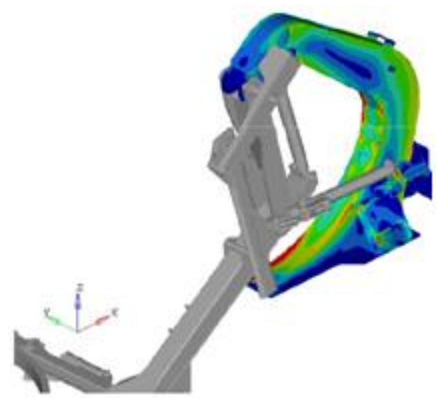

Figure 3: C-Frame Stress plot

Table 1 provides a comprehensive summary of all three hotspot regions identified in both the baseline and modified designs of the C-frame.

Table 1: C-Frame hotspot summary

	STRESS SUMMARY (psi)					
	LOCATION-1		LOCATION-2		LOCATION-3	
	Baseline	Modified	Baseline	Modified	Baseline	Modified
Load Case - 1	9000	7500	22000	15000	Negligible	
Load Case - 2	8000	3600	17000	12000	14000	13500
Load Case - 3	11000	7000	16000	14000	16000	13000
Load Case - 4	14000	9000	42000	33000	51000	45000

5. Conclusion

This paper demonstrates the effectiveness of using kinematic simulation for analyzing and optimizing automated lift systems in garbage trucks. These techniques offer valuable tools for improving performance, efficiency, and safety while minimizing operational costs and environmental impact.

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