

Structural Optimization of Truck Tanks: Safety and Structural Integrity Enhancements for Oil Transport Vehicles in Kuwait

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Abstract

This research addresses the critical problem of fluid sloshing within tank trucks, a phenomenon that significantly compromises vehicle stability, safety, and braking performance during acceleration, deceleration, and cornering. Given the intensive transportation of liquid cargo, notably petroleum derivatives in oil-centric economies like Kuwait, effective mitigation of this internal wave formation is paramount for public safety and environmental protection. The unmitigated sloshing effect in a standard smoothbore tank poses a severe structural risk, as demonstrated by a preliminary Factor of Safety (FOS) of approximately 1.76 for a common 6 mm support thickness under static load. This low FOS suggests a high susceptibility to failure when subjected to the significant transient forces of sloshing. The core objective of this paper is to optimize the internal baffle geometry of truck tanks to minimize this sloshing effect. This involved a case study using a benchmark elliptical tank design from local Kuwaiti manufacturers (ALMULLA industries), with the methodology built on rigorous Computational Fluid Dynamics (CFD) analysis. The CFD model was validated by successfully replicating an established academic study on liquid sloshing. The iterative optimization process led to the final, superior design: The Upper Welded Baffle with Three Cuts. This optimized configuration yielded substantial, quantifiable improvements compared to the initial smoothbore design: **Dynamic Pressure Reduction:** An 83.4 % reduction in the maximum dynamic pressure exerted on the tank walls, **Fluid Velocity Reduction:** A 73.9% reduction in the maximum average fluid velocity. This paper successfully validates a CFD-based methodology for slosh mitigation and presents a practical, optimized baffle geometry and support design, for enhanced safety. The findings affirm that this structural optimization provides a highly effective means of stabilizing liquid cargo transport, offering clear justification for industry adoption by significantly increasing the safety and structural integrity of tanker trucks.

Keywords

Kuwait oil and gas industries, Fluid Sloshing, Design Optimization, Baffle Design, Tank Trucks.