Forensic Engineering Assessment of Safety for Stand Up Forklifts

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Introduction

Forklifts operated from a stand up position rather than a seated position offer a significant advantage to increase warehouse capacity. Stand up lift trucks can be operated in warehouse aisles as narrow as 8 feet. In contrast, traditional sit down lift trucks typically require aisles approximately 11 feet wide. Aisle width reduction can increase warehouse capacity approximately 20 to 25 percent. However, a significant hazard exists with the use of stand up lift trucks that does not exist with sit down lift trucks; the hazard of a horizontal rack beam entering the operator compartment and crushing the operator. Sit down lift trucks are equipped with a roll over protective structure typically comprised of a canopy supported by four vertical posts. Stand up lift trucks are typically equipped with an overhead guard to protect the operator from falling objects, however, the rear of the canopy is not typically supported by posts. The overhead guard design leaves the rear of the operator compartment open, and horizontal rack beams can intrude into the operator compartment, crushing the operator between the rack and the lift truck. Hundreds of serious accidents have resulted from this hazard and over a dozen operators have sustained fatal injuries.

Another significant hazard related to stand up lift trucks is the hazard of a lower limb injury or foot crush due to the opening across the rear of the operator compartment. Numerous injuries have occurred to the lower limbs of stand up lift truck operators due to the close proximity of the operator's lower limbs to the exterior of the lift truck, and the confined areas that stand up lift trucks operate in. The operator's foot or leg can become pinned between the moving lift truck and a fixed object such as a rack system, column, or another lift truck. The accident database compiled by one of the stand up forklift manufacturers indicates that the manufacturer's stand up lift trucks have been involved in over 3,000 incidents/accidents in the last thirty years. Over 500 accidents involving lower limb injury/foot crush have occurred. Both foot crush injuries and horizontal intrusion injuries share a common theme; the operator becomes injured while the lift truck is traveling in a forks trailing manner (traveling with the forks or load end following the truck.)

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This paper will detail the hazards of horizontal intrusion and lower limb injury for the operators of stand up lift trucks, review standards related to operator protection against horizontal intrusion and lower limb injury, summarize a safety engineering analysis of the stand up lift truck design including guarding to mitigate the hazards, and present three cases tried to jury verdict regarding injury accidents on stand up lift trucks.

Key Words

Forensic Engineering, Stand Up Forklift, Safety, Guarding, Foot Crush, Horizontal Intrusion.

Stand Up Lift Trucks

Stand up lift trucks are produced in a variety of configurations. This paper is limited to narrow aisle stand up lift trucks that are end controlled, (controlled from the end opposite of the load), counterbalanced trucks, and reach/straddle trucks. An example of a stand up, end control, counterbalanced truck is shown in Figure 1, and an example of a stand up, end control, reach type truck is shown in Figure 2. Counterbalance trucks transport their load outside of the polygon formed by points of contact between the tires of the truck and the ground while reach or straddle trucks transport the load (or a portion of the load) within the polygon formed by the points of contact between the tires and ground. The primary load tires on a counterbalance truck are located directly behind the mast of the truck, while the load wheels on a reach or straddle truck are located on outriggers in front of the truck.

Figure 1
Crown RC30TT – Stand Up, End Control, Counterbalance Lift Truck

The wheel configuration of the truck dictates the turning radius and subsequently the aisle width required by the truck. Counterbalanced trucks can pivot about a point between the left and right front load wheel and typically have a turning radius of approximately 4-5 feet, while reach and straddle trucks can turn about a point located midway between the front load wheels, and have a turning radius of approximately 5-6 ft. Because counterbalance trucks have a

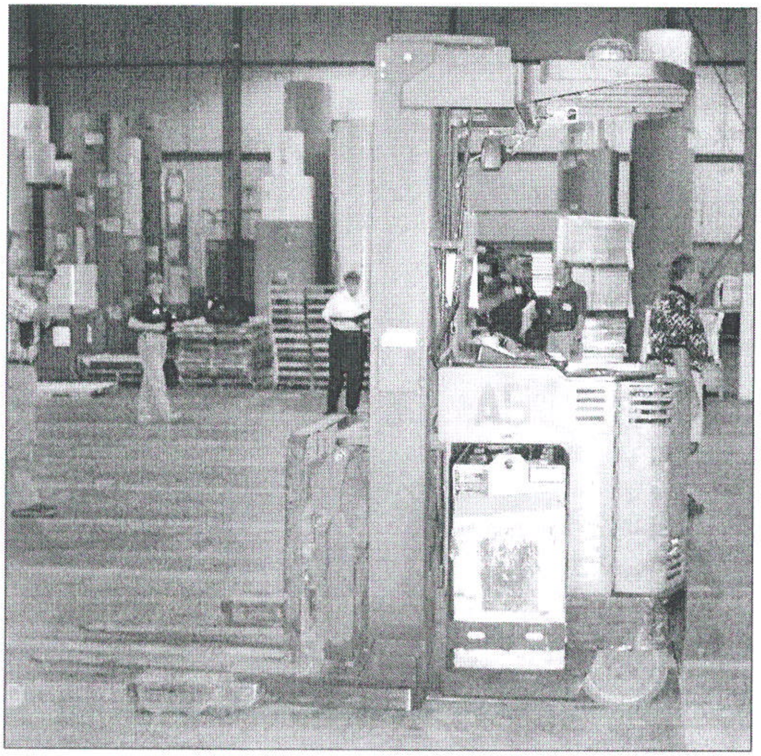

Figure 2
Raymond 31i-DR30TT – Stand Up, End Control, Deep Reach Truck

shorter wheelbase than reach trucks, counterbalance trucks can operate in slightly narrower aisles that reach trucks. Reach/Straddle or narrow aisle trucks can typically handle larger loads than counterbalance trucks, and lift loads to greater heights. Reach trucks are typically equipped with a pantograph or scissors mechanism to extend the load away from the mast. Straddle trucks utilize the same basic chassis as a reach truck, but are not equipped with a reach mechanism. The pantograph mechanism on a reach truck can be doubled to allow a load to be stacked twice as deep as a straddle truck can. The ability to stack product twice as deep creates additional storage space in warehouses in that it eliminates the need for as many aisles.

Reach and straddle trucks are primarily used in warehousing applications to place loads into and remove loads from warehouse racking systems. Reach/straddle trucks have been referred to as "portable elevators." Counterbalance trucks are typically used to transport loads within warehouses, but may also be used to unload highway truck trailers at the loading dock.

The weight associated with lift trucks is typically underappreciated. A typical stand up counterbalance truck may weigh 8,000 pounds (including the battery), and be capable of moving a 3,000 pound load. The mass of a fully loaded truck is comparable to 4 Honda Civic sedans. While the weight associated with trucks is underappreciated, the kinetic energy associated with a truck is much lower than that commonly experienced in automotive applications. The stand up counter balance truck may be capable of traveling at speeds on the order of 7-8 mph empty (speeds are typically lower when loaded). The kinetic energy of a fully loaded truck moving at top speed is equivalent to the kinetic energy of an automobile moving at twice the speed (approximately 14 mph). The kinetic energy of an automobile traveling 65 mph has approximately 22 times the kinetic energy of a stand up counterbalanced lift truck. Therefore protecting the occupant of a lift truck should be simpler than protecting the occupant of an automobile from a kinetic energy management standpoint.

Hazard of Horizontal Intrusion

While the use of narrow aisle lift trucks decreases the area of the warehouse that must be devoted to aisles, the volume of material stored on pallets can also be increased to increase warehouse storage capacity. When the amount of material stored on a single pallet increases without increasing the width or depth of the pallet, the height of the load increases. To accommodate the increased height of the pallet and load, the height of the rack beams (or shelf heights) must be increased to accommodate the size of the load. When the height of the first rack beam from the floor is raised above the height of the rear wall of the operator compartment, and is lower than the overhead guard, the rack beam can intrude into the operator compartment.

The penetration of the rack beam into the operator compartment can occur with the truck moving at speeds as high as 7-8 miles per hour (mph). Such a collision would certainly cause significant injuries to the operators. However, the speed of the collision is not the most significant factor. Considering the mass of the truck, even a collision between the operator of a truck and a rack at 1-2 mph can produce substantial force, or can compress the operator between the truck

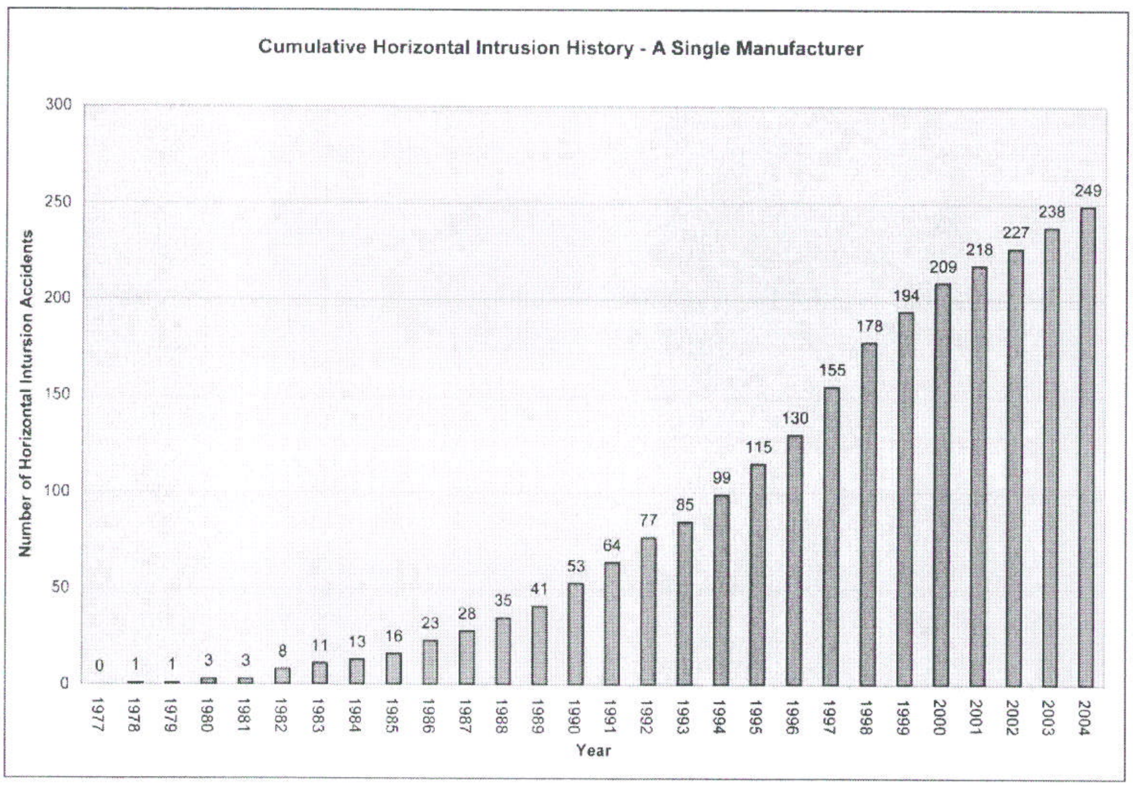

Figure 3
Cumulative Number of Horizontal Intrusion Incidents