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HAZARD ANALYSIS AND RISK ASSESSMENT FOR THE OPERATORS OF STAND-UP FORKLIFTS

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ABSTRACT

Past studies have indicated that the greatest risk that a forklift operator faces is the hazard of an overturning forklift crushing the operator. This conclusion has been developed largely based on accident experience with sit-down forklifts. In contrast, this paper examines a data set of approximately 3,000 stand-up lift truck accidents (rather than sit-down forklifts) and finds that the operator of a stand-up lift truck is at greater risk of being involved in a collision with a stationary object than at risk for an accident involving the stability of the forklift. Greater than 50% of the approximately 3,000 accidents studied involved a collision between a stand-up forklift and a stationary object, resulting in approximately 700 serious injuries and 22 deaths of stand-up forklift operators. This paper will also identify the hazards associated with the use of stand-up lift trucks and the statistical likelihood of the hazard based on the approximately 3,000 accident data set.

Keywords: Lift truck, forklift, injury, accident

INTRODUCTION

In March of 1988 the Industrial Truck Association (ITA) petitioned the Occupational Health and Safety Administration (OSHA) to revise the standard for training of operators of powered industrial trucks (forklifts). As a part of the rule making process, OSHA [1] began to study the issue of forklift safety and found that forklift accidents cause approximately 85 fatalities and 34,900 serious injuries every year. The ITA [2] and OSHA have recognized different classes of powered industrial trucks and OSHA [3] has recognized that different hazards exist with the operation of the different classes of powered industrial trucks. OSHA concluded that each of the different classes of powered industrial trucks had a different "feel," and that the workplaces where the powered industrial trucks presented particular hazards. Based on this conclusion OSHA generalized the hazards into three different categories, and recognized hazards based on the following criteria [4]:

1. Hazards associated with the particular make and model of truck
2. Hazards of the workplace
3. General hazards that apply to the operation of all or most industrial trucks

Despite the recognition that each class or type of powered industrial truck presents particular hazards, the data available to OSHA typically did not recognize the different classes of powered industrial trucks and typically lumps all powered industrial truck accidents into a single category despite the class of the truck. Analysis which lumps accidents involving all classes of powered industrial trucks into a single category will recognize hazards that apply to the operation of most industrial trucks, but will likely emphasize the hazards of the largest class of powered industrial trucks.

To evaluate whether further operator training would mitigate powered industrial truck injuries OSHA studied the type of accidents that forklifts are involved in, the effectiveness of training, and whether additional training would have prevented accidents. The data that OSHA reviewed that categorized accident type suggests that forklift tipover or overturn is involved in the greatest number of accidents. When OSHA reviewed data from the Bureau of Labor Statistics (BLS) [5], OSHA found "forklift overturned" involved in 24 percent of 170 fatal accidents, the single largest category of accidents. The Office of Data Analysis (ODA) of OSHA's Directorate of Policy examined 53 fatal accidents that occurred between 1980 and 1986. The ODA study found that 22 of the 53 fatal accidents (42 percent) involved the operator being crushed by a tipping vehicle [6]. Both of these

studies suggest that the highest number of accidents occurs in the category of forklift tipover accidents.

The National Institute for Occupational Health and Safety (NIOSH) published an alert in 2001 [7] to prevent injuries to the operators and those who work near forklifts. NIOSH investigations indicated that many workers and employers were not aware of the risks of operating or working near forklifts. NIOSH found that forklift overturns were the leading cause of fatalities involving forklifts, representing approximately 25% of all forklift related deaths. NIOSH further found that the three leading causes of forklift fatalities were forklift overturns, workers on foot being struck by forklifts, and workers falling from forklifts. The NIOSH study did not identify any hazards associated with forklift collisions.

This study will examine a data set of nearly 3,000 accidents of ITA Class 2, Lift Code 1 and 3, and Class 1, Lift Code 1 Electric Motor, Narrow Aisle Powered Industrial Trucks (solid tire). The data set is maintained by a manufacturer of electric powered industrial trucks, and is limited to the narrow aisle, end control, stand-up rider trucks including straddle, reach and counter balanced trucks. Narrow aisle trucks are defined by the Industrial Trucks Standards Development Foundation (ITDSF) [8] as a powered industrial truck that is primarily intended for right angle stacking in an aisle narrower than those normally required by (*sit-down*) counter balanced trucks of the same capacity. Stand-up, end control trucks are operated from a standing position with the operator located at the end of the truck opposite from the load end. Straddle and reach trucks carry a load within the polygon formed by the contact points of their tires with the ground while counterbalanced trucks carry the load outside of the polygon form by the contact points of the tires. The data set represents accidents reported to the manufacturer, but likely does not represent all accidents that have occurred on the manufacturer's stand-up, end controlled trucks.

The database has been maintained by the manufacturer since 1977 to the present time. The manufacturer began producing narrow aisle forklifts in 1974 with annual production of 100's of units in the mid 1970's, increasing into the 1,000's of units from the late 1970's through the present day. Production peaked at approximately 8,000 units in 2000. The total number of trucks produced through the year 2004 was approximately 100,000. The database utilized for this analysis was completed in January of 2005 and contains 2,918 accidents [9]. As stated previously, the accident database likely does not contain all accidents that have occurred on the stand-up, end controlled forklifts produced by the manufacturer so the likelihood of the accident may be understated; however it seems likely that the relative proportion of accident categories should be accurate.

METHODOLOGY

Accidents recorded within the data set have been categorized into 6 categories or hazards. Several of the categories also contain subclasses. The risk (the probability of an injury resulting from the hazard) of each accident type and subclass will be identified. No attempt will be made in this study to determine the cause of the accidents, however, operator protection for significant categories or hazards will be discussed.

The categories of accidents that have been identified included stability related accidents, pedestrian accidents, collision accidents, maintenance accidents, fall accidents, and unknown or unclassified accident. Stability accidents include three subclasses including forklifts tipover (tipping 90 degrees), forklift tip (tipping less than 90 degrees), and off-dock accidents where the forklift falls from a loading dock. Pedestrian accidents have been separated into two subclasses including pedestrian collisions with forklifts, and pedestrian accidents where the pedestrian is caught between the forklift and a fixed object. Collision accidents include four subclasses. Collisions accident included collisions between two moving objects, a collision with a fixed object, an object intruding into the operator compartment and colliding with the operator, and horizontal intrusion accidents where a horizontal member such as a rack beam intrudes into the operator compartment and collides with the operator. Maintenance accidents included accidents where an individual is injured performing maintenance on the forklift. Fall accidents occur when an individual falls from the elevated forks of the forklift. Unknown or unclassified accidents include accidents in which too little information has been collected to generate a complete accident report or the accident does not readily fit into established categories.

FINDINGS

Breaking the 2,918 accidents into the 6 categories of accidents identified for narrow aisle, end controlled stand up lift trucks shows that the most likely accident that a stand-up, end controlled truck will be involved in is a collision type accident. Note that the 2,918 accidents include fatal accidents, accidents where serious injury has occurred, accidents where no injury has occurred, and accidents where the level or injury is unknown or property damage has occurred. After collision, the accident categories that narrow aisle, end controlled trucks are most likely to be involved in are stability accidents, unknown\unclassified, pedestrian, maintenance and fall. Table 1 summarizes numerically the category of accident, number of accidents, and percentage of accidents that the category represents, while Figure 1 graphically summarizes the same data. The data set can also be evaluated based solely on fatal accident data and on fatal and serious injury data. Table 2 and Figure 2 summarize the fatal accident data, and Table 3 and Figure 3 summarize fatal/serious injury accident

data. Serious injury has been defined as 3 consecutive lost workdays.

Category of Accident	Number of Incidents	Percentage
Collision	1693	58
Stability	635	22
Unknown/Unclassified	265	9
Pedestrian	194	7
Maintenance	116	4
Fall	15	0.5
Total	**2918**	**100%**

Table 1. *Statistical Breakdown of 6 Accident Categories*

Category of Accident	Number of Incidents	Percentage
Collision	22	42
Stability	19	36
Unknown/Unclassified	1	2
Pedestrian	6	11
Maintenance	1	2
Fall	4	7
Total	**53**	**100%**

Table 2. *Statistical Breakdown of 6 Accident Categories – Fatal Accident*

Category of Accident	Number of Incidents	Percentage
Collision	767	73
Stability	87	8
Unknown/Unclassified	59	6
Pedestrian	98	9
Maintenance	31	3
Fall	13	1
Total	**1055**	**100%**

Table 3. *Statistical Breakdown of 6 Accident Categories – Serious Injury/Fatal Accident*

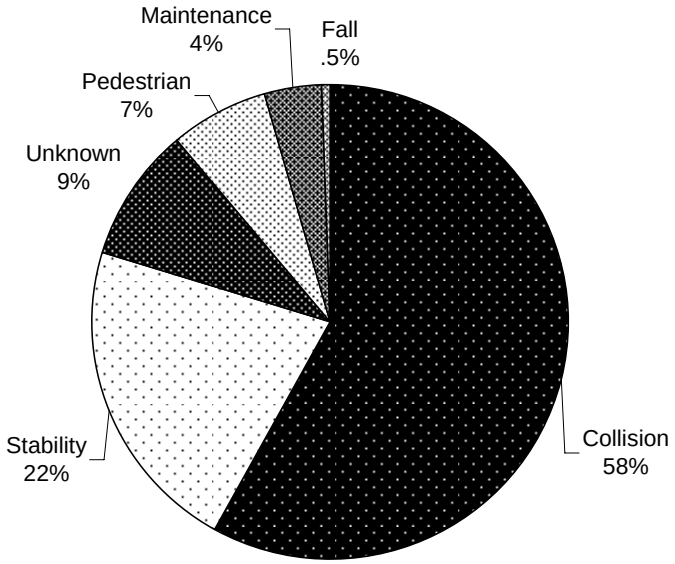

Figure 1. *Graphical Representation of Accident Categories*

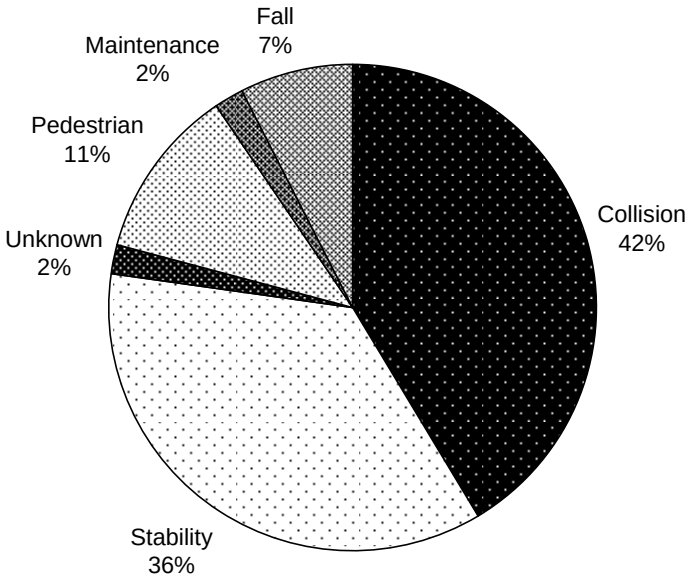

Figure 2. *Graphical Representation of Accident Categories – Fatal Accidents*

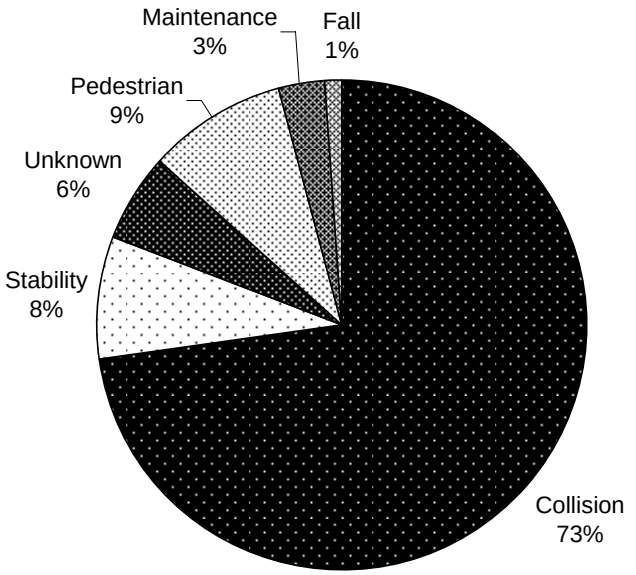

Figure 3. *Graphical Representation of Accident Categories – Serious Injury/Fatal Accidents*

DISCUSSION

Hazard can be defined as the potential for an activity, condition, or circumstance to produce harmful effects or an unsafe condition. Based on the data set described above 5 distinct hazards can be identified for stand-up end controlled forklifts. The hazards include collisions, stability accidents, pedestrian accidents, maintenance, and fall accidents. Each of these hazards has the potential to produce serious injury or property damage. Risk can be defined as the expected frequency of an event and the consequence of a single accident. Examination of the data set shows that the most common accidents involve collision, stability, and pedestrians.

Examination of the data set shows that the most common category of accident that a stand-up, end controlled forklift will be involved in is a collision. This conclusion remains true regardless of whether the entire data set is considered or the subsets of fatal accidents and serious injury/fatal accidents are examined. Stand-up end controlled forklifts are nearly 3 times as likely to be involved in a collision than a stability accident (1698 collision accidents compared to 635 stability accidents). The data set also indicates that collision accidents are more likely to generate a serious injury/fatality than stability accidents. Stand-up end controlled forklifts were involved in 1,698 accident that generated 767 serious injuries or a fatality (approximately 45% of collision accidents) while the 635 stability accidents generated 87 serious injuries or fatalities (approximately 14% of stability accidents). Table 3 shows that 73% of all serious injury/fatal accidents on stand-up end controlled forklifts resulted from a collision accident. Therefore, stand-up end controlled lift trucks are 9 times more likely to produce a serious injury or death due to a collision than a stability accident. Based on this data the conclusion can be drawn that the risk of a collision accident is the highest (or a collision is the most likely accident) and the most likely to produce a serious injury/fatal accident.

Past studies that have been performed by OSHA and NIOSH have noted that the most probable cause of a fatal accident is an overturn or tipover accident. Apparently this conclusion has been drawn from a number of accidents involving sit-down forklifts where the operator falls or jumps from the operator compartment while the forklift over turns, and the operator is crushed between the overhead guard and the ground. The statistics generated by a review of the accident histories of stand-up end controlled lift trucks shows that overturns or tipovers are a significant cause of fatal injuries, however collision accidents have caused more fatalities and serious injuries.

Collision accidents can and have been broken down into several subclasses of the general category of collision. The subclasses include a collision between two moving objects, a collision with a fixed object, an object intruding into the operator compartment and colliding with the operator, and horizontal intrusion accidents where a horizontal member such as a rack beam intrudes into the operator compartment and collides with the operator. Injuries to operators of stand-up end controlled forklifts may be prevented through the use of additional guarding. ITSDF B56.1 Safety Standard for Low Lift and High Lift Trucks Section 4.5.3 [10] currently recognizes that the use of additional guarding may be required to enhance safe operation of the vehicle, and references Sections 7.30 and 7.36 which discuss the use of guarding to limit horizontal intrusion, and operator enclosures (doors). Typically vertical posts extending from the body of the lift truck to the overhead guard and/or extended backrests/extended walls of the operator compartment have been utilized to prevent horizontal rack beams from entering the operator compartment. Operator enclosures or doors across the open end of the operator compartment have been suggested to prevent intrusion injuries and to prevent injuries in the event of a collision with a fixed object. A more complete discussion of the hazards of horizontal intrusion and lower leg crush is presented in Ziernicki et al [11].

Zoghi-Moghadam et al [12], [13] have presented research that suggests that the use of an operator enclosure or door would be detrimental to risk reduction based on simulation of off-dock stability accidents involving stand-up end controlled forklifts. Zoghi-Moghadam et al concluded that a door would be detrimental based on head, and neck loading found from analysis of testing and simulation of off dock accidents. Similar reasoning was previously used to argue against the use of seat belts in sit-down forklifts; however seat belt use in sit-down forklifts is now mandatory. The primary flaw in this reasoning is that humans have the ability to brace themselves within the operator compartment, while test dummies do not.

A more detailed explanation of the relationship between head injury criteria (HIC) and seat belt use in sit-down forklifts and the ultimate conclusion that seatbelts should be used in sit-down forklifts can be found in Carlin et al [14].

Furthermore, Berry [15] has found that the average injury to the operator of an end controlled stand-up lift truck involved in stability accidents is greater when the operator is ejected or jumps from the operator compartment than when the operator stays within the operator compartment. This finding is consistent with the current industry conclusion that operators of sit-down forklifts should remain inside the vehicle during a tipover. The most significant injury mode in stability accidents is the risk of being crushed between the ground and an overturning lift truck, rather than the risk of a head injury due to remaining in the truck during a stability accident. Berry's findings regarding stability type accidents further indicate the need for additional guarding for collision accidents since operators will not be exposed to greater risk in stability accidents by the addition of a door to the operator compartment. The significant risk of serious injury and death in collision accidents suggests that additional guarding on stand-up lift trucks would prevent a significant number of injuries and deaths.

Fatal accidents follow the general trend observed above in that collision accidents cause more fatalities; however, fatal injuries result more regularly in stability accidents than collision accidents. Collision accidents have included 22 fatalities (out of 1,698 accidents) while stability accidents include 19 fatal injuries (out of 635 accidents). Stability accidents are causing fatal injuries in 3% of accidents while collision accidents are causing fatal injuries in 1.3% of accidents. The data set shows that while collision accidents are more likely, and are more likely to produce serious injuries, stability accidents are more likely to cause fatal injuries. Stability accidents generate a significant number of injuries and fatalities due to the significant energy associated with an approximately 8,000 pound lift truck falling four to five feet off of a loading dock.

Reduction of the risk of off dock accidents begins with the design of the loading dock and the selection of material handling equipment used on the loading dock. The first step in the prevention of off dock accidents should focus on preventing forklifts from falling off of the dock. Physical barriers across dock openings may be used when trailers are not at the dock. When a trailer is at the dock, trailer locking devices that secure the rear under ride guard (ICC bar) or the axle may be used. At a minimum, trailer wheel chocks and the trailer's brakes should be set. The choice of material handling equipment should be examined recognizing that off dock accidents have occurred and caused fatal injuries. Many warehouses opt to use sit-down lift trucks to load and unload tractor trailers, apparently due to the fact that sit-down forklifts have seat belts and roll over protective structures (ROPS) while stand-up forklifts do not. Sit-down forklifts offer significant protection to the operator of a lift truck in the event of an off dock accident that stand-up lift trucks do not. Stability accident can also be prevented through the use of additional control equipment on lift trucks. Many manufacturers of lift trucks are now adding equipment to lift trucks to prevent stability accidents, by introducing active suspension systems, and active mast control systems. Such controls will reduce the number of tipover accidents away from the dock.

CONCLUSION

The hazard of sustaining serious or fatal injuries for operators of stand-up end controlled forklifts due to a collision has been found to be more significant than the hazard of serious or fatal injuries due to a stability accident. The risk of sustaining serious or fatal injury can be mitigated through the use of additional guarding. Vertical posts extending to the overhead guard and/or extended walls/extended backrests surrounding the operator compartment will prevent injuries associated with horizontal intrusion collisions. The use of an operator enclosure or door on the opening into the operator compartment will reduce injuries associated with collisions. The use of an operator enclosure or door will also mitigate injuries to operators in the event of a tipover or off dock event.

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