SIE 2015
6th International Symposium on Industrial Engineering
24th-25th September 2015
FACULTY OF MECHANICAL ENGINEERING
STEINBEIS ADVANCED RISK TECHNOLOGIES
INNOVATION CENTER FME

SAFETY IN CRANE OPERATIONS: AN OVERVIEW ON CRANE-RELATED ACCIDENTS

Maria Francesca Milazzo[1], Giuseppa Ancione[1], Vesna Spasojevic Brkic[2]
[1]Dipartimento di Ingegneria Elettronica, Chimica e Ingegneria Industriale (DIECII), Università degli Studi di Messina, Italy
[2]Faculty of Mechanical Engineering (FME), University of Belgrade, Serbia

Abstract. *Moving large and heavy loads in manufacturing and construction industries is made by means of cranes. Until now, much technology has been developed for these operations, but there are significant safety issues to be considered. Cranes are amongst of the most dangerous equipment used in both the industry and construction sites. Despite the risk awareness, incidents in crane's operations have not substantially decreased; most of them arise from wrong load handlings, poor visibility in moving loads, etc. Their dangerousness has special relevance in the chemical process industry and the intermodal transport, where accidental events could also generate the release of hazardous substances. This paper focuses on safety in crane operations, the main causes of accident will be identified and a statistical analysis is presented with the aim to drawn some conclusions and comment about future trends of research about this issue.*

Key words: *Industrial safety, Crane accident, Load displacement, Human error, Cause of failure.*

1. INTRODUCTION

Cranes are widely used in the construction industry to move materials, in the transportation to load/unload cargos, in the manufacturing industry to assemble heavy equipment, etc. [6]. When installed and properly used, cranes make operations easier and safer. Nevertheless, even if the technology and risk awareness have substantially increased, safety still needs to be improved, as underlined by many crane-related accidents occurring each year worldwide.

A tipped, dropped or mishandled load can directly injure workers or potentially upset the equipment. Databases show that accidents occur in each crane typology (such as tower cranes, overhead cranes, mobile cranes, etc.); however, the highest rate of incidents is usually associated to the mobile type.

Crane accidents could be more severe if they occur in the chemical process industry and intermodal transport, where hazardous substances are handling. As an example, in 2011 an incident occurred in the Orica Chemicals refinery at Kooragang Island, near Newcastle, in New South Wales; this event involved a mobile crane and was due to the overturn of the machine after that one of its outriggers punched through the ground into some sort of void [16]. In such case, the release of dangerous substances could also take place and, depending on the characteristics of the released substance, the event escalation could also generate fires, explosions and toxic dispersions.

Several crane-related incidents are also caused by the contact between the load and objects or other equipment; this is mainly due to the limited visibility for the crane operator. Significant are also incidents due to the contact with powerlines [7].

This paper is focused on safety in crane operations: the first part present the methodology adopted for the investigation of incidents, which is based on a short description of the risk factors (hazards or initial cause of accidents) and the identification of associated accident typologies; the second part gives the results of a statistical elaboration of the collected accidents; a brief discussion about the results concludes the work with the aim to comment about future trends of research concerning this issue.

2. METHODOLOGY

To investigate the issue of the safe in crane operations, the adopted methodology starts with the analysis of main related risk factors and, then, some databases of accidents have been analysed to collect data and identify the main initial causes of accident.

2.1 Crane safety issues

Cranes use one or more simple machines to create mechanical movement for the displacement of loads. The load movement is controlled either by an operator, placed in a cab that travels along with the crane through a push button pendant control station, or by radio type controls. The crane operator is ultimately responsible for the safety of the crews and the crane [13]. Another cause of failure can be found in crane design [2]. According to [5], crane issue reports show that poor human performance is increased over time as a cause of failure and it currently accounts between 70 and 80 percent of all detected problems. In U.S. nuclear industry, the human error rate for very heavy load transport accounts 56 % and is less than the human error rate observed when considering other crane uses (73 percent). The same report [5] gives data for the energy sector, it can be seen that the human error contribution is about 94% (the same value has been observed in navy cranes), where improper operation, improper rigging and procedure failures account approximately 88 %.

The trend of the poor human performance in period 1969-2002, as a cause of crane issues, is shown in Figure 1.

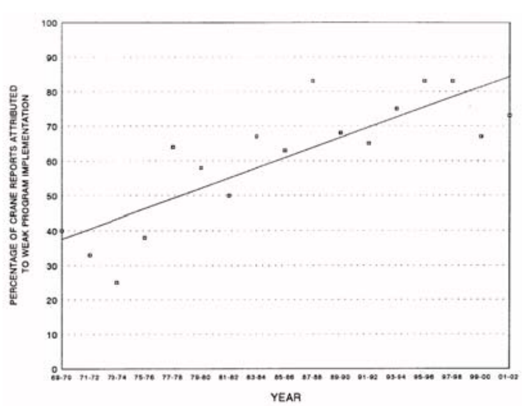

Figure 1. Trends of poor human performance as a cause failure in crane operations [5].

According to Shapira and Simcha [8], which paid special attention to tower cranes, human factor is a dominant factor, affecting the site safety due to tower-crane operations, within which operator performance has the highest weight. This has also been confirmed by the survey reported in [10].

2.2 Hazard types

There are multiple hazards that can arise during cranes' operations. Many accidents involve lift systems, such as in tower cranes and mobile cranes, but other hazards do exist by operating with all types of cranes and in all facets of crane operation [15]. According to the American Federal Agency OSHA (Occupational Safety and Health Administration) the major causes of cranes-related accidents are [11]:

- Contact with powerlines
- Overturns
- Falls
- Mechanical failures

The causes of accidents, listed above, could determine the following main causes of fatality for workers, which were identified by the CPWR (Center for Construction Research and Training) [4]:

- Electrocution
- Struck by crane load
- Crane collapse
- Struck by falling boom

There are also several near misses that should have the potential to escalate into incidents that incurred massive damages to both human lives and physical properties. The magnitude associated with such events increases with the decrease of the number of incident according to the Bird triangle [3].

Table 1-4 summarise the main initial causes of fatal accidents for each cause of fatality listed above. Data refers to the period 1992-2006 and have been collected from U.S. Bureau of Labor Statistics - Census of Fatal Occupational Injuries (CFOI) [12].

Table 1. Overhead power lines / Electrocutions

Causes of incident	**[%]**
Contact of workers with cable	52
Crane operations	25
Contact of worker with crane	13
Other / unknown causes	10

Table 2. Struck by crane loads

Causes of incident	**[%]**
Workers accidental involved in the accident (except crane operators)	32
Workers flagging/directing/guiding the load movement	14
Loading / unloading	32
Crane operations	7
Other crane-related work	15

Table 3. Crane collapses

Causes of incident	**[%]**
Uneven / unstable or icy surface	15
Crane cables / rigging / broken stabilisers	14
Crane load / boom shifted	9
Overloaded	12
Other / unknown causes	51

Table 4. Struck by Falling Booms

Causes of incident	**[%]**
Dismantling boom	56
Broken boom / broken boom cable	13
Lengthening boom	9
Other / unknown causes	22

3. RESULTS

The analysis of the available databases allows commenting about crane-related accidents. The graphical elaboration, given in Figure 4, highlights that in a reasonably long period (from 1992 to 2006) the number of fatalities in crane-related accidents (occurred in the construction industry) have not undergone a significant reduction. The trend could be considered constant.

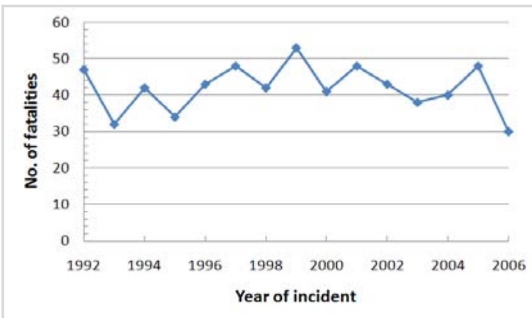

Figure 4. Trend of the number of fatalities associated with crane-related accidents in construction [4].

Figure 5 summarises the major causes of lethal accidents [4] and provides the overall percentages of fatality for each of them. Furthermore it is important to underline that several other crane accidents determine injuries and equipment damage and property losses. These consequences determine undesired stops due to the absence of operability (missed work days) and increasing insurance rates.
A study, done by OSHA in 1997, reported that the majority of crane accidents are non-fatal and most injuries do not involve crane operators but other workers (such as ironworkers, riggers, carpenters [11] and sometimes bystanders, rescue workers, etc.).

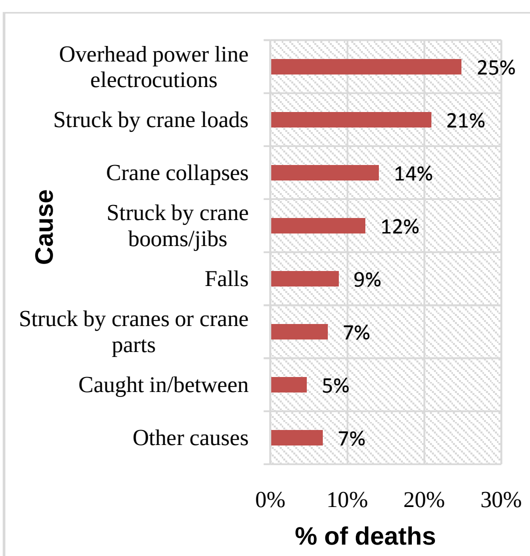

Figure 5. Causes of crane-related deaths [4].

3.1. Future trends of research

In order to minimise visual problems, improving safety and preventing crane related fatalities and injuries, some authors [9] identified the critical characteristics of existing crane cabins linked to the visibility and the posture by using users' opinions and Pareto analysis.
As highlighted by the literature [1], incidents due to impacts between the crane or its load and objects or other equipment are often due to limited or poor visibility of the surrounding workspace (from the crane operator point of view). The crane navigation system is an important and challenging phenomenon, with a great potential for safety improvement. Although the typical crane operator interface seems simple in terms of the number of controls to be manipulated, moving the spreader quickly and accurately, with or without a container, requires an exceptional sense of its dynamics, including how to effectively stop the moving mass often facing the "stabbing in the blind" scenario. To fill this gap a project, entitled *Smart PRocess Industry CranEs* (SPRINCE), was recently funded with the aim to improve the safety for crane operator by implementing an innovative real-time detection system of objects and developing a risk indicator for the implemented solution.

4. CONCLUSIONS

Accidents involving cranes can severely damage people and companies. Unfortunately these show a constant trend in term of number of fatalities over the years. By analysing the causes of accidents, the highest percentage is associated with the electrocution, but the contribution of impacts with the load and the crane (strikes) is also significant.
To further improve safety, there is the need of a more integrated approach, where design safety and safety in the use fields are considered as one entity [2], with more attention paid to human error issues.
The literature has highlighted the main needs for crane design (capability to be safely operated, easy maintenance and reduction of typical human problem factors), but up to now worldwide research has not been focused on the crane navigation system.
The need of a new solution for crane visual tension problems has emerged from this investigation of accidents and will be partly faced within the SPRINCE project.

ACKNOWLEDGEMENT

This research is part of a project entitled "Smart PRocess Industry CranEs (SPRINCE)", which is supported by the consortium ERA-NET SAF€RA - Coordination of European Research on Industrial Safety towards Smart and Sustainable Growth under the Seventh Framework Programme for Research and Technological Development.
The University of Messina and the University of Belgrade, respectively, acknowledge INAIL (Istituto

Nazionale per l'Assicurazione contro gli Infortuni sul Lavoro) and MESTD (Ministry of Education, Science and Technological Development) for the funding of the SPRINCE project.

REFERENCES

[1] Cheng T., Teizer J. (2014). Modeling tower crane operator visibility to minimize the risk of limited situational awareness. *ASCE Journal of Computing in Civil Engineering*, 28(3), 04014004.

[2] Häkkinen, K. (1993). Crane accidents and their prevention revisited. *Safety science*, 16(3), 267-277.

[3] Hughes P., Ferrett E. (2011). Introduction to Health and Safety at Work. Routledge.

[4] McCann M. (2010) Understanding Crane Accident Failures: A report on the causes of death in crane-related accidents. Crane & Rigging Conference on the causes of crane-related deaths, 27 May 2010.

[5] NUREG-1774. (2003) A Survey of Crane Operating Experience at the US Nuclear Power Plants from 1968 to 2002. US Nuclear Regulatory Commission, Washington, DC, 20555-0001.

[6] OSHA (2014). Directive CPL 02-01-057, October 17th, 2014.

[7] Paques J.J. (1993). Crane accidents by contact with powerlines. *Safety Science*, 16(2), 129–142.

[8] Shapira, A., Simcha, M. (2009). AHP-based weighting of factors affecting safety on construction sites with tower cranes. *Journal of Construction Engineering and Management*, 135(4), 307-318.

[9] Spasojevic Brkic V.K., Klarin M.M., Brkic A.D.j. (2015). Ergonomic design of crane cabin interior: The path to improved safety. *Safety Science*, 73, 43-51.

[10] Tam, V. W., Fung, I. W. (2011). Tower crane safety in the construction industry: A Hong Kong study. *Safety science*, 49(2), 208-215.

[11] www.allcrane.com/. Website ALL Erection & Crane Rental Corporation. Accessed 15th June 2015.

[12] www.bls.gov/. Website U.S. Bureau of Labor Statistics - Census of Fatal Occupational Injuries (CFOI). Accessed 23rd June 2015.

[13] www.engineeringcivil.com/. Website (Indian) Civil Engineering Portal. Accessed 15th June 2015.

[14] www.sarens.com/. Website of the global leader in crane rental service and heavy lifting & special transport service. Accessed 18th June 2015.

[15] www.spanco.com/. Website of the industry leading manufacturer of overhead material handling solutions, including gantry cranes, jib cranes, and bridge cranes. Accessed 19th June 2015.

[16] www.vertikal.net/. Website Anglo – German on news and views on the world's lifting industry. Accessed 28th June 2015.