Proceedings of the 2016 Winter Simulation Conference
T. M. K. Roeder, P. I. Frazier, R. Szechtman, E. Zhou, T. Huschka, and S. E. Chick, eds.

A PROTOTYPE FOR SIMULATING THE KINEMATICS OF CRANE RIGGING OSCILLATORY MOTION USING SIMPHONY.NET

Ronald Ekyalimpa
Martin Akolo Chiteri
Simaan AbouRizk

University of Alberta
Department of Civil and Environmental Engineering
NREF/Markin CNRL Building
Edmonton, AB T6G 2W2, CANADA

ABSTRACT

Crane hoisting operations represent a significant portion of the work scope on construction sites, especially those that have adopted a modularized approach to construction. Creating metrics that can be used in the automation of these processes can result in higher jobsite efficiencies from a safety and productivity perspective. This study created a virtual simulation environment prototype that can be experimented with to generate the required metrics for crane hoisting automation. The equation of motion for this oscillatory motion was first defined. Thereafter numeric solutions to this equation were explored from a continuous simulation perspective using Simphony.NET. Then prototyping of simple pendulum motion was implemented using the continuous simulation services in Simphony.NET and verification done using Mathematica.

1 INTRODUCTION

The construction industry's core business entails the production of infrastructure/facilities or components that are used in the erection of infrastructure/facilities. Just like any other production system, one of the major concerns of construction is the handling of various materials, most of which are bulky. Effective material handling requires logistics that facilitate their material manufacture, transportation/distribution, storage/warehousing, and disposal. Examples of such logistics include: manual, semi-automated, and automated equipment. There is a wide range of machines that fall in these categories, these include: conveyors, hoisting equipment, industrial robots, pallet jacks, lift trucks, etc.

There have been a number of trends in material handling that have been started with the sole purpose of improving the efficiency with which material handling is done. The first of these trends was started by Fredrick Taylor who is also regarded as the founding father of the industrial engineering domain (Robinson 2015). Taylor did most of his work in the area of improving manual loading processes and his work led to subsequent efforts that resulted in mechanization of the material handling process and later the automation of the machines used. The study presented in this paper seeks to follow this trend and further efforts that strive to achieve higher efficiencies in material handling. The focus is restricted to hoisting equipment, specifically cranes, because they are the most predominant type of equipment utilized in construction. For example, cranes are used for handling and lifting precast concrete sections, steel pieces, vessels, equipment, modules, etc., within construction sites. There are a number of issues that exist in rigging operations. The one being dealt with in this study is presented in the section that follows.

978-1-5090-4486-3/16/$31.00 ©2016 IEEE

7 CONCLUSIONS AND RECOMMENDATIONS

Background information has been presented on crane rigging operations along with the issues that face them. This research work was done as a starting point for addressing issues that arise from excessive oscillation of suspended objects. Crane rigging was abstracted as a simple pendulum. A number of simplifying assumptions were made and a prototype (i.e., no damping and a stationary fixed support) formulation and continuous simulation model completed to demonstrate the feasibility of adapting a simulation-based approach to addressing the issues. The formulations, model, and the results generated are precise.

Developed prototypes can be used as a basis for creating enhanced formulations and simulation models that mimic the actual crane rigging operations more precisely. For example, excitation to the suspended object can be introduced by the initial motion of the main support – as is the case in actual rigging operations. Also, damping effects can be explicitly accounted for so that the time that it takes for excited suspended objects to come to rest in different conditions can be investigated. It was also assumed that the sling attached to the object does not deform during the oscillatory motion. Numeric methods will be used to model the deformation of this sling as the oscillatory motion progresses. Once this phase has been completed successfully, robotic prototypes can be experimented with in a lab prior to deployment on cranes and other rigging equipment within the field. Robotic lab experiments can be done in parallel with simulated animations and visualization of the kinematics of rigging operations. This is one of the main reasons that simulation was explored as a way of abstracting this physical oscillatory motion.

REFERENCES

Chopra, A. K. 2012. *Dynamics of Structures: Theory and Applications To Earthquake Engineering*. 4th ed. Upper Saddle River, New Jersey, Pearson Education, Inc., publishing as Prentice Hall.

Coulton, J. J. 1974. "Lifting in Early Greek Architecture." *The Journal of Hellenic Studies* 94: 1–19, doi:10.2307/630416.

Department of Energy (DOE). 2002. *Hoisting and Rigging Fundamentals for Riggers and Operators*. Report Number: TR244C, Rev. 5

Fedock, S. Dennis, and The Babcock and Wilcox Company. 1999. *"Construction Loads Produced During Heavy Lifting, Rigging and Handling Operations."* American Society of Civil Engineers, 1999 Structures Congress.

Kreyszig, E. 1999. *Advanced Engineering Mathematics*. 8th ed. 605 Third Avenue, New York: John Wiley & Sons.

Infrastructure Health & Safety Association. 2012. *Hoisting and Rigging Safety Manual*.

Robinson, A. 2015. The Evolution and History of Supply Chain Management. Accessed April 9, 2016. http://cerasis.com/2015/01/23/history-of-supply-chain-management/.

UL Workplace Health & Safety. 2012. "Basic Rigging for Construction." Accessed April 23, 2016. http://ondemand.puresafety.com/course-library/basic-rigging-construction.

Vincoli. 2000. "Rigging." *Jeffrey W. Lewis' dictionary of occupational and environmental safety and health."* Boca Raton: Lewis Publishers.

AUTHOR BIOGRAPHIES

RONALD EKYALIMPA is a Post-doctoral Fellow in Construction Engineering and Management at the University of Alberta. His email address is rekyalimpa@ualberta.ca.

MARTIN AKOLO CHITERI is a Masters Student in Construction Engineering and Management at the University of Alberta. His email address is chiteri@ualberta.ca.

SIMAAN ABOURIZK is a University Professor and NSERC Industrial Research Chair in Construction Engineering and Management at the University of Alberta. His email address is abourizk@ualberta.ca.