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ScienceDirect

Procedia Engineering 106 (2015) 108 – 125

Procedia Engineering

www.elsevier.com/locate/procedia

Dynamics and Vibroacoustics of Machines (DVM2014)

Novel control method for overhead crane's load stability

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Abstract

Nowadays, cranes are widely employed in many fields of the industry and its utilization represents a large financial influence. The investment on cranes, for example, on docks are mainly associated with the time required for the positioning of the cargos. The objective in this experiment was to develop the control of a system to minimize the stabilization time of a load swinging due to crane movement using a controller created from a Lyapunov function. A metal structure was used with a pendulum, attached to a linear motor. After the controller was designed and implemented a series of experiments were done in varied conditions of mass and signal input. The system can be moved at high speed with the joystick and a trigger is pressed to quickly stabilize the pendulum. This, compared to the traditional methods of controlling this payload oscillation has made evident that the control method associated to the use of a joystick can reduce the loading time and also eliminate the need of a highly experienced driver operating the crane.

Peer-review under responsibility of organizing committee of the Dynamics and Vibroacoustics of Machines (DVM2014)

Keywords: Control engineering; Lyapunov function; Lyapunov method; Automatic control engineering; Block diagrams; Linear motors

1. Introduction

Cranes are essential machinery on modern world and are used to perform tasks which require the movement of heavy loads in different fields of industry such as construction, transportation or in manufacturing for the assembly of heavy components. There are several types of cranes which are selected according to the specific task to be performed. These cranes can be divided in overhead, fixed or mobile cranes. In the categories of fixed or mobile categories there are also lots of subdivisions, for example, fixed cranes can be tower cranes, telescopic cranes,

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Peer-review under responsibility of organizing committee of the Dynamics and Vibroacoustics of Machines (DVM2014)
doi:10.1016/j.proeng.2015.06.014

gantry cranes, etc. Mobile cranes can be truck-mounted crane, carry deck crane, floating crane among many others. The main focus in this project is the study of the overhead cranes [1].

The fields in which overhead cranes are more useful are mainly inside factories to move heavy machinery or to assembly heavy equipment. This kind of crane is also used for moving containers on harbors [1]. The objective when operating a crane is to move an object from one place to another avoiding collision with other objects and placing it with the best possible accuracy. However, due to the inertia on the movement of the load, the object being moved is subject to oscillation and this is a problem that must be always avoided [2], [3], [4].

Many different approaches have been taken in order to mitigate the effects of the sway. A predictive approach was used by Singer et al. [12] by input shaping to prevent the load from ever swinging in 1997. A position and swinging compensation method was proposed with a proportional-derivative control by Fang et al. [13]. Wen Yu proposed a similar controller adding an uncertainty compensation neural network [14]. An observer based control was design and tested in a real bridge crane by Aschemann et al. [15]. Ahmad used delayed feedback signal and PD-type fuzzy logic controllers in a two-dimensional model of a gantry crane [16]. William Singhose et al. developed and implemented sway reduction by an input shaping controller compensating the motion induced oscillations [11].

The goal in this work is to design a control system that minimizes swinging of the load carried by the crane. A Lyapunov-based approach was taken in this research. Since stability can be a crucial factor in any control application that was decided to be the starting point for the stabilization of the load. For this a linear motor model Siemens 1FN3150 2WC0 (located in LUT's Laboratory of Intelligent Machines) was used with a metal structure attached to it. In this metal structure a pendulum is held and oscillates simulating the crane movement. The used equipment is shown in figure 1 (a). Also, the aim is to optimize the process making the movement and stabilization of the pendulum as fast and swiftly as possible.

Nomenclature

m	mass of the pendulum
R	length of the pendulum rod
x	horizontal position of the system
θ	angle of the rod
$\vec{r}$	position vector
$\vec{v}$	velocity vector
T	kinetic energy
V	potential energy
Q_θ	friction force
μ	friction coefficient
e	error
$V(\theta)$	lyapunov function

2. Control method

This section describes how the system was modeled into equations which were then used to design and implement the controller. Stability is analyzed and ensured introducing the necessary background regarding Lyapunov.

2.1. Mathematical model

The system can be modeled as shown in Figure 1 (b). A moving cart plays the part of the motor while a mass m hanging from a rigid bar of length R simulates the pendulum. The moving motor can be assumed to have no friction with the ground.