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Abstract

Title	Load Sway Suppression for Rotary Cranes Using Simple Dynamics Model and Motion Trajectory

(800 words)

Rotary cranes are widely used to transport heavy loads and hazardous material in industrial applications such as shipyards, factories, nuclear installation, railway yards, and high building construction. One dimensional horizontal boom motion of such cranes typically generates undesirable two dimensional load sway, therefore, skillful crane operators are requested to control it manually based on their experiences to suppress the load sway at the desired position. Failures of crane control cause accidents, injure people, and damage surroundings. The main purpose of this thesis is to propose a controller for suppressing load sway caused by horizontal boom motion effectively.

We propose a robust controller design with respect to rope length (natural frequency) variance of the rotary crane. If the control system considers the effect of rope length variance, the crane's motion can be controlled without a sensor system for measuring it. Because the control system is also expected to be robust with respect to varying parameters such as joint friction, load mass variance and boom horizontal velocity, we consider a controller design on the basis of a disturbance observer to provide a linear dynamics of the rotary crane motion. We design a state feedback controller with an integrator to achieve robust control performance for a given range of variations in rope length. The proposed control system satisfies additional constraint conditions on closed-loop pole placement. These conditions are expressed in terms of linear matrix inequalities (LMI), and controller gains are determined numerically via LMI optimization.

Both horizontal and vertical boom motion were used in the LMI approach to suppress load sway. It would be less energy intensive and also safer if a control scheme could be developed using only horizontal boom motion, i.e. without the need for any vertical motion that must overcome gravity. For this purpose, we propose a nonlinear controller design that can suppress two dimensional load sway using only horizontal boom motion. The controller design is based on a disturbance observer and partial linearization. This design provides a simple dynamical model of rotary crane motion that includes a centrifugal force term responsible for two dimensional load sway. An anti-sway controller design based on the Lyapunov stability theory is presented. This controller provides tracking control of the boom along an arbitrary trajectory while suppressing two dimensional load sway.

Because the proposed two methods above, LMI optimization based method and Lyapunov stability theory based method, used load sway information measured by sensor systems in real time, their hardware costs may be higher. In addition, since cranes are inherently stable system, feedback control seems undesirable, especially when applied to welfare and nursing works. Therefore, we propose a control scheme that can suppress two dimensional load sway using only horizontal boom motion without requiring load sway information. By focusing on residual load sway suppression, a simple S-curve trajectory for horizontal boom motion is generated analytically and numerically. This simple trajectory can be applied to inexpensive industrial controllers.

The effectiveness of the proposed methods is demonstrated by numerical simulations and experimental results.