Title: Active Control of an offshore container crane

Abstract
Open sea loading/unloading cargo provides a potential solution to minimize problems related with port construction, expansion and congestion. This process involves a crane attached to a mobile harbor which dynamically handle container from a large container anchored in deep water. The control objective during the operation is to keep the payload in the desired position under the presence of ocean waves. This paper presents a robust control strategy for trajectory tracking and sway suppression of an offshore container crane. The asymptotic stability of closed-loop system is guaranteed by a control law derived for the purpose. Experimental results are provided to indicate the efficiency of the proposed control strategy.

Problem Statement
In recent years, with the rapid increase of world trade as well as the need for larger container ships, shipping companies have resorted to an increase of the vessel size. So as to keep up the ever-increasing ship sizes, researchers has applied several ways to deal with new trend. One possible option is to improve the efficiency and productivity in cargo handling demands. In addition, the container carriers have to become larger, and faster thanks to suitable controllers that can improve fast turn-over times and meet safety requirements. Despite these improvements, many container terminals still face with two problems: (i) the difficulty to accommodate the mega container ships due to the shallow water depth, and (ii) the port congestion due to the increase of cargo ships. Fortunately, though, a special crane-equipped ship, or mobile harbor (MH), capable of open-sea loading-unloading of containers from a large anchored container ship, or mother ship, is a potential solution. The control methods developed for conventional quay cranes are inapplicable to mobile harbor carnes. Thererefore, the new control strategy for the mobile harbor is identified, and treated, from a control point of view.

Contributions
This study describes the design process of a new offshore crane control strategy to show its efficiency through experiments in a prototype model. At first, the dynamic model of an offshore container crane is derived, after that system verification is conducted to verify the proposed mathematical model. Next, the control structure is developed, which is contains two mechanism. The path generation part plays a role of creating suitable trajectory for trolley movements. This motion is now being used both for sway suppression and for keeping the payload in the desired position. Finally, the authors proposed the Fuzzy Sliding Mode Control (FSMC) for mobile harbor cranes based on its non-linear model. A component of this control method is a sliding surface that accounts for payload swing, MH motion and the trolley position in order to achieve satisfactory system responses. In addition, according to the proposed control strategy, the control gain has a value large enough for sliding surface to reach sliding mode quickly and also for counteracting the uncertainty of the system. As sliding mode has started, this strategy will allow decreasing the gain in order to avoid chattering phenomenon. A stability analysis and experiments are performed to prove the asymptotic stability of the closed-loop system.

Results

Fig. 1 Roll motion of MH

Fig. 2 Experimental results without MH motion

Fig. 3 Experimental results with MH motion

Conclusions
In this paper, the new control schemes for trajectory tracking and anti-swing control problem of MH crane was addressed. The path generation plays a role of creating suitable trajectory for trolley movements. In the proposed control law, the control gain has a value large enough for sliding surface to reach the sliding mode quickly and also for counteracting the uncertainty of the system. As sliding mode has started, this strategy will allow decreasing the gain in order to avoid chattering phenomenon. The derived control law guaranteed the asymptotic stability of the closed-loop system. Also, the main advantage of the proposed control structure in robustness, using a rope length variations in crane model, was demonstrated.

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