H_∞ controller with graphical LMI region profile for Gantry Crane System

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***Abstract*— This paper presents investigations into the development of H_∞ controller with pole clustering based on LMI techniques to control the payload positioning of INTECO 3D crane system with very minimal swing. The linear model of INTECO 3D crane system is obtained using the system identification process. Using LMI approach, the regional pole placement known as LMI region combined with design objective in H_∞ controller guarantee a fast input tracking capability, precise payload positioning and very minimal sway motion. A graphical profile of the transient response of crane system with respect to pole placement is very useful in giving more flexibility to the researcher in choosing a specific LMI region. The results of the response with the controllers are presented in time domains. The performances of control schemes are examined in terms of level of input tracking capability, sway angle reduction and time response specification. Finally, the control techniques is discussed and presented.**

Keywords - INTECO 3D crane*; *sway control; H-infinity; LMI region.

I. INTRODUCTION

The main purpose of controlling an underactuated crane system is transporting the payload in a precise location. However, it is very difficult due to the fact that the payload can exhibit a pendulum-like swinging motion. Various attempts in controlling cranes system based on open loop and closed-loop control system have been proposed. For example, open loop time optimal strategies were applied to the crane by many researchers [1,2]. Poor results were obtained in these studies because open-loop strategy is sensitive to the system parameters and could not compensate for the effect of wind disturbance. In other hand, feedback control which is well known to be less sensitive to disturbances and parameter variations has also been adopted for controlling the crane system. For example, PD controllers has been proposed for both position and anti-swing controls [3]. However, the performance of the controller is not very effective in eliminating the steady state error. In addition, fuzzy logic controller has also been proposed for controlling the crane system by several researchers [4]. However, the fuzzy logic designed still need to struggle in finding the satisfactory rules, membership function, fuzzification and deffuzification parameter heuristically. In addition, since crane system is an underactuated system, sliding mode control also has been proposed by bringing the sliding surface into to the system [5]. Furthermore, the underactuated crane behavior also gives a very challenging problem in achieving good trajectory planning. A few contribution of trajectory planning scheme have been reported in [6]–[12].

In this project, H_∞-synthesis with pole clustering based on LMI techniques is used to control the positioning of payload with very minimal swing. In order to design the controller, the linear model of INTECO 3D crane system as shown in Figure 1 is obtained using the system identification process. The reason for choosing H_∞-synthesis is because of its good performance in handling with various types of control objectives such as disturbance cancellation, robust stabilization of uncertain systems, input tracking capability or shaping of the open-loop response. Nevertheless, the weakness of H_∞ controller is in handling with transient response behavior and closed-loop pole location instead of frequency aspects [13]. As we all know, a good time response specifications and closed-loop damping of underactuated crane system can be achieved by forcing the closed-loop poles to the left-half plane. Moreover, many literatures have proved that H_∞ synthesis can be formulated as a convex optimization problem involving linear matrix inequalities (LMI) [14]-[16]. In this case, the normal Riccati equation with inequality condition was used. This behavior will give wide range of flexibility in combining several constraints on the closed loop system. This flexible nature of LMI schemes can be used to handle H_∞ controller with pole placement constraints. In this study, the pole placement constraints will refer directly to regional pole placement [17]. It is slightly difference with point-wise pole placement, where poles are assigned to specific locations in the complex plane based on specific desired time response specifications. In this case, the closed-loop poles of crane system are confined in a suitable region of the complex plane. This region consists of wide variety of useful clustering area such as half-planes, disks, sectors, vertical/horizontal strips, and any intersection thereof [17]. Using LMI approach, the regional pole placement known as LMI region combined with design objective in H_∞ controller should guarantee a fast input tracking capability, precise payload positioning and very minimal sway motion. As an extension of previous work, this report presents a graphical profile of the transient response of crane system with respect to pole placement constraint variation. This graphical analysis is very useful in giving more flexibility to the researcher in choosing a specific LMI region.

The rest of this report is structured in the following manner. The next section provides a description of the linear model of underactuated crane system based on system