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Dynamic Analysis of the Cable Array Robotic Crane

Wei-Jung Shiang
David Cannon
Department of Industrial and Manufacturing Engineering
Jason Gorman
Department of Mechanical Engineering
Pennsylvania State University
University Park, Pennsylvania

Abstract

Offshore loading and unloading of cargo vessels and on board cargo relocation during conditions of Sea State 3 or greater have been found to be difficult with existing crane technology due to oscillation of the payload. A new type of crane which uses four actuated cables to control the motion of the payload is presented. The closed chain configuration will intuitively provide more stability with respect to the motion of the sea compared to existing cranes. The kinematics and dynamics are derived using cable coordinates. Since there are four cables and three degrees of freedom, the system is redundant. This problem is solved by applying a geometric constraint to the equations of motion such that the reduced number of equations equals the degrees of freedom. The force distribution method is applied using linear programming to solve for the required cable tensions. Simulation results showing cable tensions and cable lengths during a typical crane operation are presented.

1 Introduction

Offshore loading and unloading of cargo vessels and on board cargo relocation during conditions of Sea State 3 or greater have been found to be difficult with existing crane technology. The sea state may directly cause large motions of the cargo ship or indirectly introduce large motions of the hoisted container with the effect of excitation of parametric instability.[4] Traditional cranes are stable only in the vertical direction while they load are free to rotate in all directions and sway in the horizontal plane under the slightest side disturbance.[5]

Many investigators have introduced robotics concepts such as parallel manipulators to design stiffer crane systems [1], [5], and [10]. They argued that the most efficient structural form for carrying large steady loads is a set of tension members and compression members configured to hold the load with the lowest possible loads in each member.[10] The advantages of parallel manipulators are high precision positioning capability, fast motion, large lifting capacity, and light weight.[9]

The four-cable array robot shown in Fig. 1 is proposed to manipulate a container load in an efficient way on the vessel deck by controlling the length of all four cables simultaneously. This closed chain system has three constrained degrees of freedom while the remaining three degrees of freedom are controlled by an end effector.

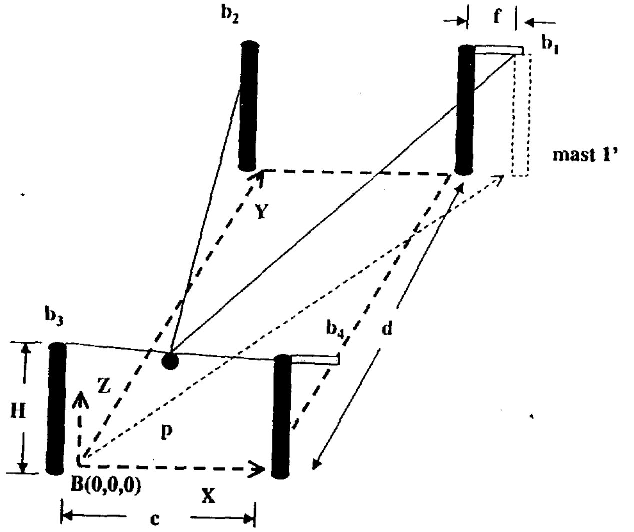

Figure 1: Schematics of the cable array robot

Four cables are used rather than three so that the workspace on deck is maximized. However, this advantage increases the complexity of the problem by causing the system to be kinematically redundant.

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