Dynamic Analysis and Control of Flexible Long Boom Manipulator

This project is aiming at the complex dynamics and control problems of flexible long boom manipulator, which is equipped by mobile cranes and aerial platform vehicles. The long boom manipulator consists of flexible boom structure and hydraulic drive system. This multi-physical system can be described as a port-Hamiltonian system by port-based modelling method. A structure-preserving numerical algorithm will be applied to solve the large-scale differential-algebraic equations of Hamiltonian system.

Starting Points

The boom system of mobile cranes and aerial platform vehicles can be considered as a long boom manipulator that consists of single or multiple long and light booms, using hydraulic actuators along with an electro-hydraulic servo system to control movements. Due to the long boom system, mobile cranes are suitable for lifting tasks with large radius and height, whereas aerial platform vehicle can transport persons and equipment to high operation positions for installation, maintenance or fire rescue missions. The longest boom-system of mobile cranes has reached the length of 250 meter and the highest position that can be reached by aerial platform vehicles is 114 meter.

In order to reduce the dead load and to ensure the mobility as well as transportability, the boom systems are always designed as light as possible. The boom structures with limited stiffness are always performing a strong flexible behavior, even though the strength of the boom system is ensured. Due to the dynamic behavior of hydraulic actuators (hydraulic cylinders or motors) which derives from the elastic hydraulic oil and flow characteristics of hydraulic components, the output of the hydraulic system during start-up and braking stages of the operations could significantly fluctuate. The combination of the elastic drive system and the flexible boom structure leads to a hybrid system with complex nonlinear dynamic behavior. The flexibility of the boom structure can cause a intense vibration response during the operation. Furthermore, for these large scale boom systems, the dynamical load due to inertia cannot be neglected during boom movement. The structure vibration will increase the maximum dynamic stress which could cause structure fatigue or even structure failure. Not even to mention the oscillation of the hoisting load and platform caused by the vibration respond of the boom’s tip. Such oscillation could increase the difficulty of load locating and endanger the safety of the personnel on platforms. The vibration suppression for these large scale boom systems is essential for improving the structure fatigue lifecycle, operation efficiency and personnel safety.

Objective

The objective of the project is to built a complete model of long boom manipulator and design the control law to achieve the vibration suppression. A mathematic model in the formulation of port-Hamiltonian system will be established including the boom structure and the hydraulic drive system. In order to solve this complex nonlinear ODEs problem a numerical solution method will be de-
Corresponding control strategies will be developed based on the port-Hamiltonian representation of the hybrid system.

**Approach**

Firstly, the planar beam model will be used to describe the planar motion of boom system. Then the FEM model and modal model will be used to describe the dynamic behavior in space. Suitable state variables will be selected and transferred to acquire a proper port-Hamiltonian formulation of hydraulic system. In order to solve the nonlinear dynamic problem, a structure-preserving method will be established to make time-space structure-preserving discretization of differential equations and discretize the algebraic equations at the time points. The vibration control tasks will be divided as trajectory planning and local active vibration suppression. The mathematic model will be written as optimal control problem to investigate proper control strategies.

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