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Design of a remote operation control system for vibration suppression of a liquid container by an overhead traveling crane

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In this research, a remote-operation control system for a liquid (molten metal) container transport by an overhead crane system is proposed. The proposed control system in this research allows an operator to control a speed of an overhead crane freely and to feel a swing of the rod instinctively through the reaction force, and can be controlled from everywhere used via the internet. Also, it is able to suppress liquid vibration (sloshing) in a container. The usefulness of the proposed control system is demonstrated by an experiment.

Keywords: *overhead traveling crane, vibration suppression of the liquid container, remote operation*

1. Introduction

For a liquid container transfer of molten metal by an overhead crane system in the steel and the casting industries, the construct of transfer system that can be transfer to the destination in a short time and suppress sloshing (liquid vibration) in a container, has been desire from the view point of both safety and efficiency.

On the other hand, a remote-control can also be applied in a various fields, and research and development for it systems are carried out in many fields [1],[2],[3]. In particular, Miyoshil[2] introduced a wave filter in the scattering theory to constrain the norm and were able to apply scattering theory to the system including non-passive material by using the small gain theorem of norm. We have designed a remote control system of a liquid container to be transported by an overhead traveling crane, but it does not implement the sloshing suppression in a container [3].

A design method the remote-operation control system for a liquid container transported by an overhead crane system is suggested. The proposed control system allows an operator to control the speed of an overhead crane freely and to feel a swing of the rod instinctively through the reaction force. In remote control, the information of the distant place is very important. Particularly, feeling the reaction force for operation is important like watching the rod's movement with cameras. And the proposed control system can be used via general internet and can be controlled from everywhere. Also, it is able to suppress the sloshing in the container.

The operator in a good working environment can be perform work comfortably by using the proposed the remote-operation control system. Furthermore, the proposed control system is able to suppress the sloshing, unskilled operator is able to operate easily. The usefulness of the proposed remote-operation control system is demonstrated by an experiment.

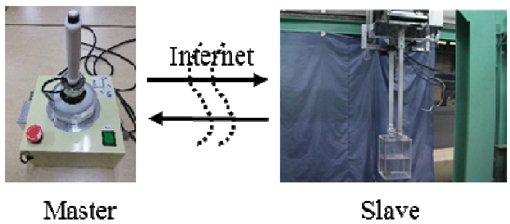

Fig. 1. Overview of the remote-control system

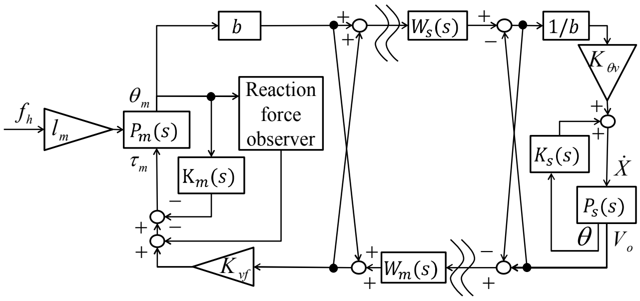

Fig. 2. Block diagram of the remote-control system.

2. Remote-operation control system

Figure 1 and 2 shows overview and block diagram of the remote-operation control system. The remote-operation control system is constructed based on a design method Miyoshi[2]. The proposed control system can be used via general internet and can be controlled from everywhere. In Fig.2, $P_m(s)$ and $P_s(s)$ are the model of master and slave respectivly, these model are expressed as Eq.1 and Eq.2.

$$P_m(s) = \frac{\theta_m(s)}{\tau_m(s)} = \frac{1}{J_m s^2 + D_m s + l_m K_h} \qquad (1)$$

$$P_s(s) = \frac{\theta(s)}{\dot{X}(s)} = \frac{ms}{mls^2 + mg} \qquad (2)$$

where J_m is a moment of inertia, D_m is a viscosity coefficient, l_m is a paddle length of the master, K_h is a input gain. m is a mass of container, l is a length of rod for hanging the container. Also, $K_m(s)$ is a controller for reaction force, $K_s(s)$ is a controller for sloshing supression. $W_m(s)$ and $W_s(s)$ are wave filter(phase lead compensator), $K_{\theta v}(s)$ and $K_{vf}(s)$ are propotional gain, b is conversion factor.

The operator provides input angle θ_m by operating the paddle of the master, and the cart velocity $\dot{X}$ of crane proportional to the angle θ_m is entered. The swing angle θ of rod for hanging the container is detected as an output value from the cart velocity, and the velocity of container V obtain same manner. The container velocity will be feed back to the operator as a reaction force of the master.

3. Experimental results

The proposed system is verified two aspects of a remote-operation control experiment between NIT,T.C(National Institute of Technology, Toyota College) and T.U.T.(Toyohashi University of Technology). The Master arm is installed in NIT,T.C and an overhead crane Slave is installed in TUT, with the internet acting as the communication line in these experiments. There is a straight distance of approximately 50 km between NIT,T.C and TUT. There are constant time delays of approximately 50ms.

An experimental result is shown in Fig.3. The operator tried to transport the liquid container a distance of 0.6m and 1.5m approximately from the start point. The operator was manipulated crane while looking at the web camera. From the experimental results, the proposed remote-operate control system was confirmed to be effective in suppressing the rod vibration and sloshing

4. Conclusion

In this research, the remote-operation control system for a liquid container transported by an overhead crane system was designed. This designed control system is able to suppress the sloshing, unskilled operator is able to operate easily.

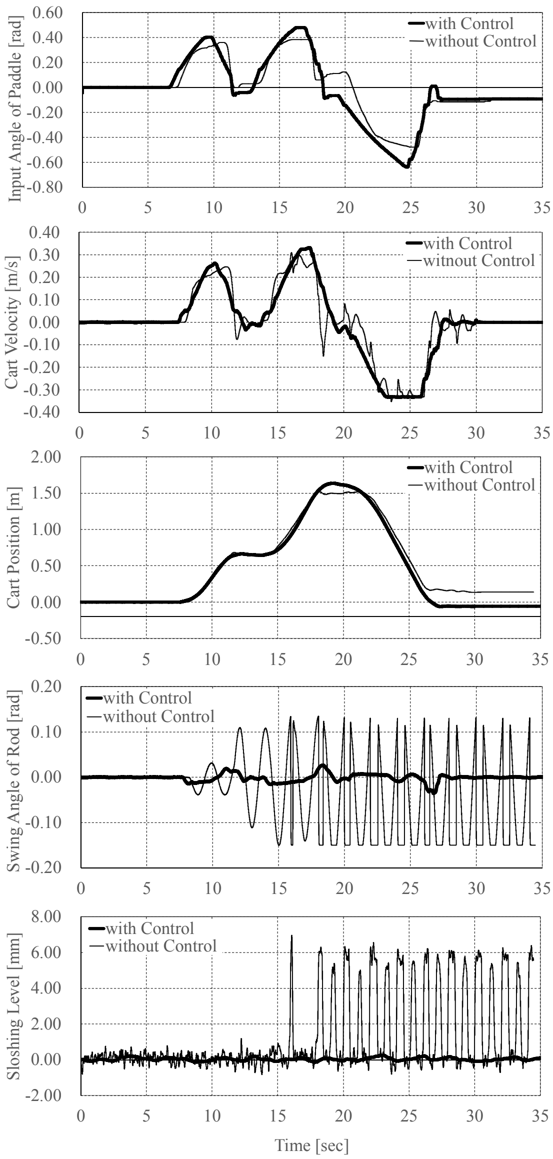

Fig. 3. Experimental results.

Acknowledgements

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