ARCH. MECH. TECH. MATER.VOL. 37 (2017) 76-78

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Design of The Test Stand for Hydraulic Active Heave Compensation System

Arkadiusz Jakubowski[a]*, Arkadiusz Kubacki[a], Dominik Rybarczyk[a]

[a] *Poznan University of Technology, Piotrowo 3 Street, 60-965 Poznan, Poland*

* *e-mail address: arkadiusz.z.jakubowski@doctorate.put.poznan.pl*

ARTICLE INFO

Received 14 March 2017
Received in revised form 14 June 2017
Accepted 22 June 2017

KEY WORDS

Heave compensation, active heave, winch system, control systems, servo valve

ABSTRACT

The article presented here described the design of a test stand for hydraulic active heave compensation system. The simulation of sea waves is realized by the use of hydraulic cylinder. A hydraulic motor is used for sea waves compensation. The hydraulic cylinder and the hydraulic motor are controlled by electrohydraulic servo valves. For the measurements Authors used displacement sensor and incremental encoder. Control algorithm is implemented on the PLC. The performed tests included hydraulic actuator and hydraulic motor step responses.

1. INTRODUCTION

Electrohydraulic servodrives are used in various types of industrial applications. Their main advantage is to achieve large forces by the small electric signal. Basic information about electrohydraulic servodrives eg. pumps, cylinders, valves are in [1,5,6,9].

Operations on the ship, such as drilling, load handling, observation of the seabed especially during rough seas are difficult to execute. For this reason, the active heave compensation is applied [10]. There are two types of heave compensation.The first is a passive heave compensation. For example Hatleskog and Dunnigan [2] studied the passive heave compensation system using a pneumatic actuator to the motion compensation drilling ship. The second way of compensation heave is an active heave compensation. Korde [3] showed the application of active heave compensation system for the ship drilling, which operates irregular waves. In this publication the ship is shown as coupled mechanical oscillators. The movement of the load can be damped by adding additional unbalance mass. Other publications describe the heave compensation during the load insertion into the water [7, 8, 4].

2. THE EXPERIMENTAL SETUP

In order to perform experimental research Authors designed the dedicated test stand. The control system was based on PLC with touch panel type Power Panel 500. The PLC was connected to the servovalves via dedicated valves amplifier (control cards). The test stand for active heave compensation system is presented in fig. 1.The control system schematic is presented in fig.2. The test stand consists of: PC (no. 13) and PLC (no. 14), which are used to control the electrohydraulic servo valves (no. 3, 4). The actual position of the hydraulic actuator (double acting cylinder) (no. 1) is measured using a displacement sensor (no. 5) and obtained results are sent to the PLC. Measuring the position of the shaft of the hydraulic motor (no. 2) is implemented by using an incremental encoder (no. 6), and is also sent to the PLC. The hydraulic motor is fixed to the actuator by the intermediate plate (no. 11). For the intermediate plate

DOI: 10.1515/amtm-2017-0012

incremental encoder is mounted on the handle (no. 12). On the shaft of the hydraulic motor a drum is mounted (no. 8) on which a steel cable is wound (no. 9). At the end of the steel cable steel load is fixed (no. 10). When lifting up and lowering the actuator a piston rod may rotate. If the piston rod rotates it will rotate all the elements mounted on the end of the piston rod. To eliminate rotating of the piston rod we use two steel bars (no. 7). Then a piston rod moves along the rod - rotation of the piston rod is blocked.

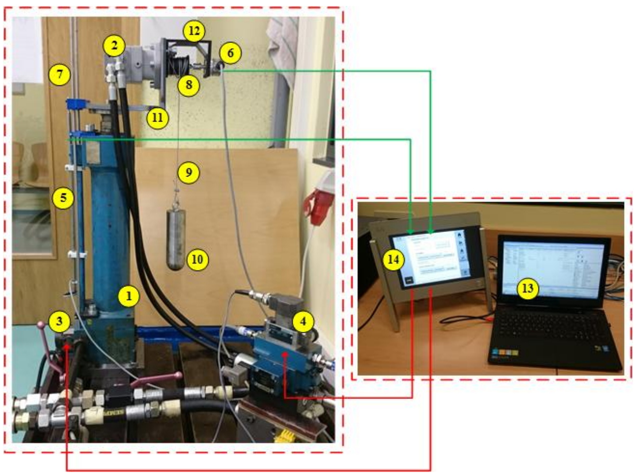

Fig. 1. The experimental stand for active heave compensation

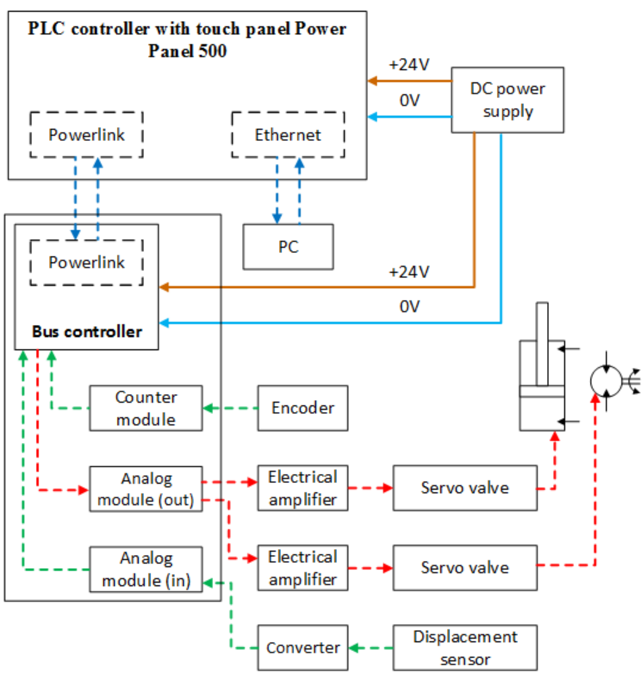

Fig. 2. The control system schematic

The hydraulic actuator and the hydraulic motor were controlled using a proportional regulator (fig. 3). The stroke of the hydraulic cylinder was equal to 400 mm. The diameters of piston were equal to: 60 mm and 100 mm. Max output power of hydraulic motor was equal to 16 kW and max rotary speed was equal to 810 rpm. The hydraulic power supply used is characterized by the following parameters: maximum flow rate= 100 dm3/min, maximum pressure p_0= 40 MPa, motor power = 37 kW, filtration at 6 microns. For measuring the actual position of the cylinder Authors used inductive displacement transducer WFS/500 with range 500 mm and for measuring the hydraulic motor actual position they used incremental encoder with range 1000 pulse rate.

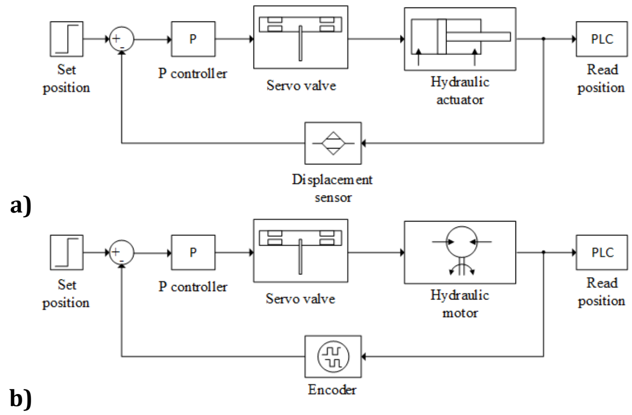

Fig. 3. P controller schematic: a) for hydraulic cylinder, b) for hydraulic motor

3. THE EXPERIMENTAL TESTS

The first step was to check step responses of the hydraulic actuator and hydraulic motor for different values of gain k_p. The experiment was performed for the supply pressure p_0 equal to 10 MPa. The collected data was shown on fig. 4 and fig. 5.The purpose of the presented above test was to examine the dynamics of the electrohydraulic drive (hydraulic cylinder) and especially hydraulic motor. The settlink time (95%) for hydraulic cylinder was T= 0,78s for k_p=40 and for hydraulic motor was T= 0,37s for k_p=80.

The next step was to perform tests of both drives (hydraulic motor and cylinder) at the same time. The load was lifted up and down by means of the hydraulic motor. The hydraulic motor followed the actuator. The hydraulic actuator was excited by the use of the step-type signal with range of 100 mm. Gain value P controller was k_p = 40 for the cylinder and k_p = 80 for the hydraulic motor. The result is shown in fig. 6. The max delay time T_{max} was equal to 100ms.

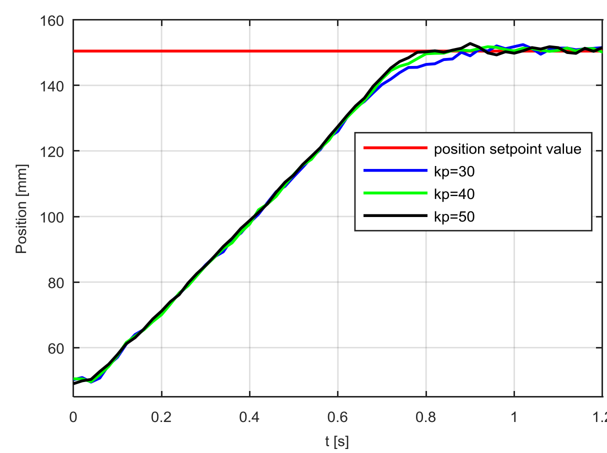

Fig. 4. The response of the hydraulic actuator at different gain of controller

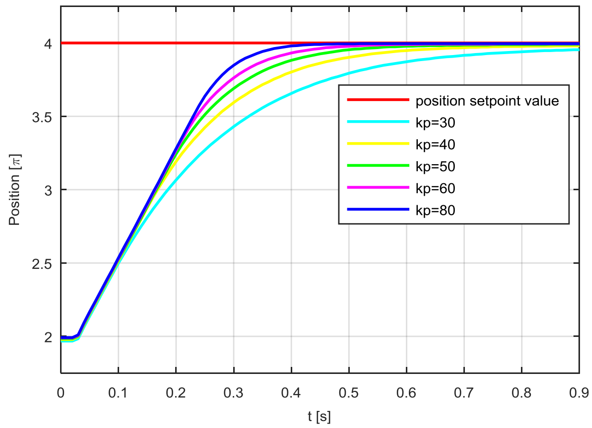

Fig. 5. The step response of hydraulic motor at different gain of controller

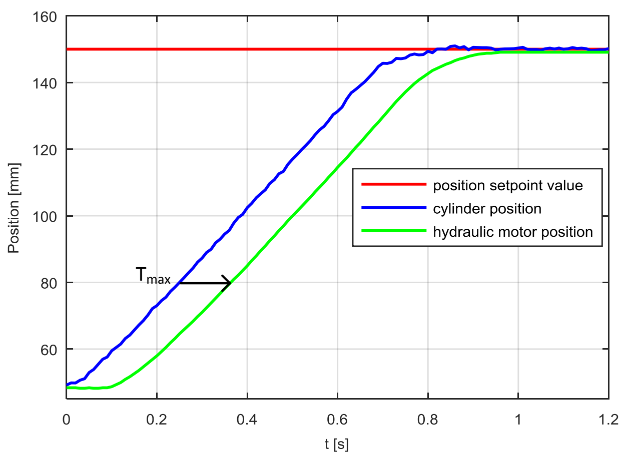

Fig. 6. The response of cylinder and hydraulic motor

The last step was to test the positioning of the hydraulic actuator and the hydraulic motor for sine signal. The actuator moved according to the sine signal. The hydraulic motor followed the actuator. The gain value P controller was kp = 40 for cylinder and kp = 80 for hydraulic motor. The period of the sine signal was T= 3s. The delay time $T_{max}$is equal to 100ms. The result is shown in fig. 7.

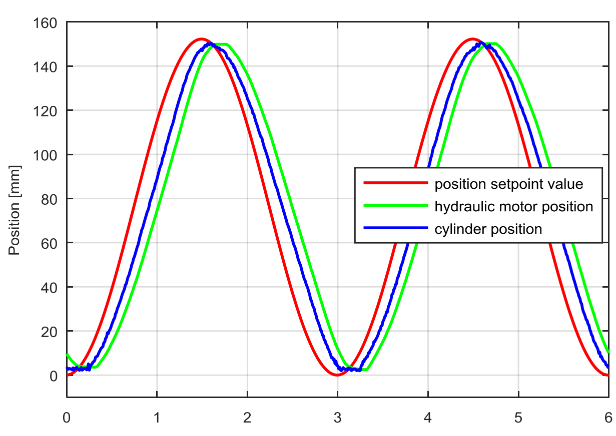

Fig. 7. The experimental results.The response of cylinder and hydraulic motorfor sine signal

4. CONCLUSION

The article describes the design of the test stand for checking of the active hydraulic heave compensation system properties. The system was tested for various parameters of the proportional controller. For the tests a test stand was built with a dedicated control system.

Further research aims to examine different variants of controllers such as PD, MPC controller and preliminary examination of the action of active heave compensation. The test stand provides installation of various type of sensors such as: accelerometer, barometer, force sensor. Through the application of these sensors it will be possible to check motion of the load and implement more complex control system.

ACKNOWLEDGEMENTS

The work described in this paper was funded from 02/23/DS-PB/120 (Nowe techniki w urzadzeniach mechatronicznych).

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