AUTOMATIC LEVELING CONTROL SYSTEM FOR COMBINE

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ABSTRACT

In harvesting rice and barley using combine, the inclination of the body caused by the irregular surface condition of the field and the soil sinking from the unbalanced weight during the grain collection used to make harvesting operation difficult and even impossible. To overcome such a problem, automatic leveling control system for a combine has been developed and tested. The system was composed of the sensor for measuring left and right inclination of the combine chassis and the hydraulic control system. The adaptability of the control system was investigated by analyzing system response in time domain. And the limit angle of the leveling control was set up to be +/- 7°. The proposed control and hydraulic power system was implemented to the prototype combine. The prototype combine was designed and built as a separable structure with chassis and track. This paper shows results of the leveling performance tested in the laboratory and the grain field.

Keywords: Leveling Control, Combine, Slope Sensor, Hydraulic Control, Modeling

INTRODUCTION

Recently, there have been many difficulties in combine harvesting because of the abnormal climate condition such as heavy rain during the rice harvest period. Rice harvesting via combine had troubles because of the soil sinkage and soil inclination caused by the increase of the wetland. Development of automatic leveling control of combine chassis has been required for a safe and comfortable harvesting operation.

Many research activities on leveling control of tractor have been reported(Tajiri 1988, Yamahachi 1997, Fukuda et al. 1982, Gravely Ltd. 1998, Lee et al. 1999). Leveling control system for combine has been developed and commercialized by Hillco Co. Ltd.(2000) and Kubota Co. Ltd.(2000). Details of design and control performance have not been reported.

In this paper, Mechanism and hydraulic system for automatic leveling control sy. were designed and manufacture. Performance of the developed system was analyzed.

MATERIALS AND METHODS

1.1 Mechanism Design

Fig. 1 shows the schematic diagram of the mechanism used for the leveling control system. Kinematic dispacement of cyliner was modeled as following.

$$(S+\Delta S)^2 = \{e-(b+c)\cos(\alpha-11.53)\}^2 + \{f+(b+c)\sin(\alpha-11.53)\}^2$$

As basic data for hydraulic system design, force acting on the cylinder was computed using Eq.(2).

$$F_c = \frac{\{(m_1+m_2)(b+c)\sin(\alpha-11.53)+m_2 i\}(S+\Delta S)}{\{f+(b+c)\sin(\alpha-11.53)\}\{(b+c)\cos(\alpha-11.53)+a\sin\alpha\}}$$

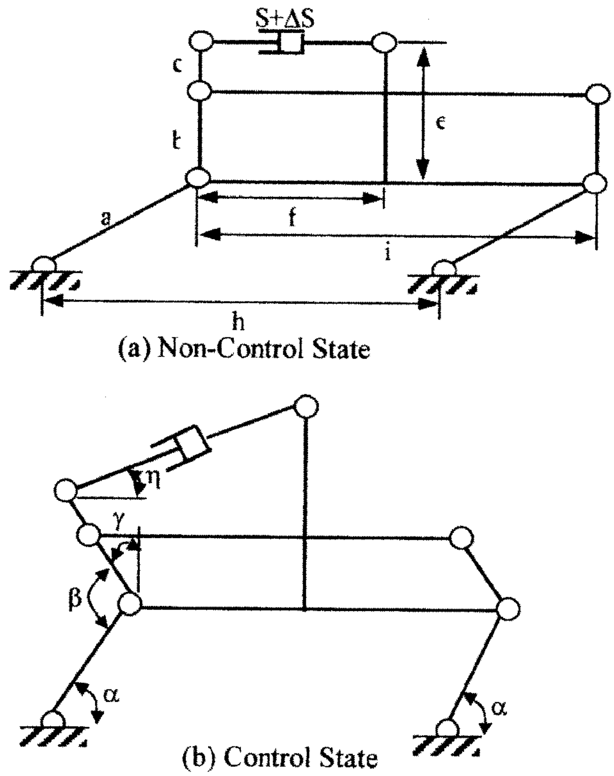


Fig. 1 Linkage of Leveling control mechanism.

1.2 Control System

Leveling control system was composed of sensory unit, control unit, and actuator unit. Displacement of hydraulic cylinder moves mechanism up and down. From the amount of the measured slope angle and the displacement of the hydraulic cylinder, control input was computed. Solenoid valve was controlled to activate the mechanism.

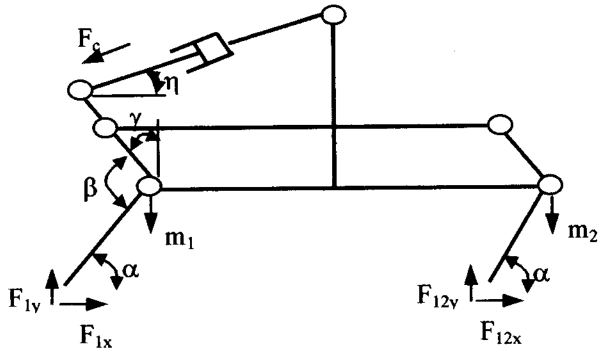


Fig. 2 Schematic diagram of force acting on the linkage.

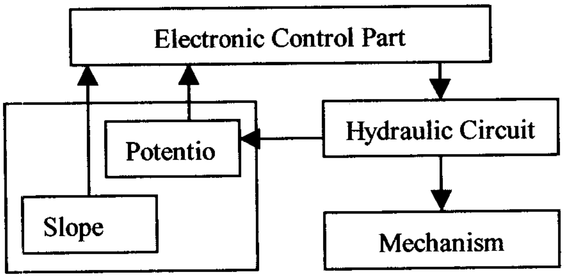


Fig. 3 Schematic diagram of control system.

RESULTS AND DISCUSSION

3.1. Indoor Test

Indoor experiment was carried out for calibration and to characterize actuating performance of each unit. Calibration was done for slope sensor and potentiometer. Up/down actuating experiment and step response was carried out to determine hydraulic pressure and flow rate.

Upward and Downward Movement Test; While manually locating combine body from the lowest to the highest position, the displacement of cylinder, oil pressure, and flow rate were measured using data recorder. Test was done by varying diameter of orifice such as 1.2mm, 1.3mm, 1.4mm, 1.5mm with the maximum engine power. Fig.4 (a) and (b) showed results of downward and upward movements respectively at diameter of 1.4mm with flow rate of *6lpm*.

During the downward motion, the discrepancy in left and right controlling speed was found because of the unbalanced force to the cylinder. It took about 2 seconds for downward movement and during the upward movement, because of the weight difference of the left and right portion of the combine, about 0.80 seconds of the difference was found between the left and the right cylinders. And it took about 3.4 seconds to reach the highest position. Dead band of the control system was 0.3°.

Step Response; Step input was arbitrarily input to the slope sensor. Step input was generated fixing one cylinder and activating other cylinder with maximum displacement. Fig. 5 shows the experiment.

Since orifice of 1.5*d* showed the abnormal overshoot, orifice of 1.4mm was chosen. Flow rate was 6.0*l*pm and time delay was 0.25sec. Settling time was about 7.5sec for the left and about 4 sec for the right. Since during the harvest, abrupt soil sinkage usually does not occur, time delay is acceptable.

3.2 *Field Test*

Step response test was done with arbitrary body rolling by traveling combine through hollows. Response on the slope according to the travel speed was also investigated

Body Rolling Test Using Hollow; Fig. 6 showed the experiment. Input flow rate was controlled by varying diameter of orifice such as 1.2mm, 1.3mm, 1.4mm, and 1.5mm. Engine power was set to be the maximum. Travel speed of the combine was set as 0.31m/sec, 0.61m/sec, 1.07m/se, and 1.38m/sec. Control system showed the stable response.

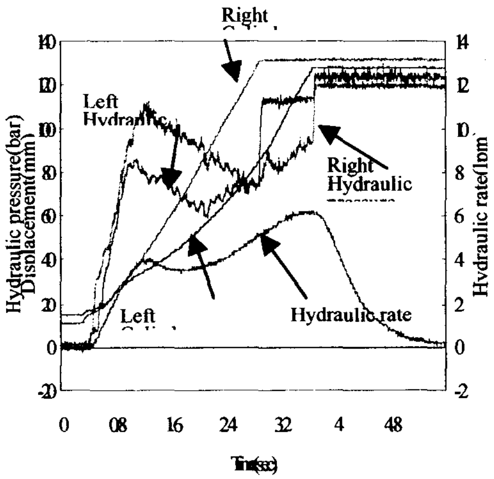
Travel angle into the hollow was limited under 7°. Field for the test was leveled. Hollow was made with 10m intervals. Orifice diameters of 1.4mm and below showed the linear stable system response. Orifice diameter of 1.5mm showed the abnormal overshoot with vibration and gave the inconsistent pulse control.

Travel Test; Input flow rate was controlled by varying diameters of orifice such as 1.2mm, 1.3mm, 1.4mm, 1.5mm and engine power was set as maximum. Travel speed of the combine was set as 0.31m/sec, 0.61m/sec, 1.07m/se, and 1.38m/sec. Control system showed the stable response.

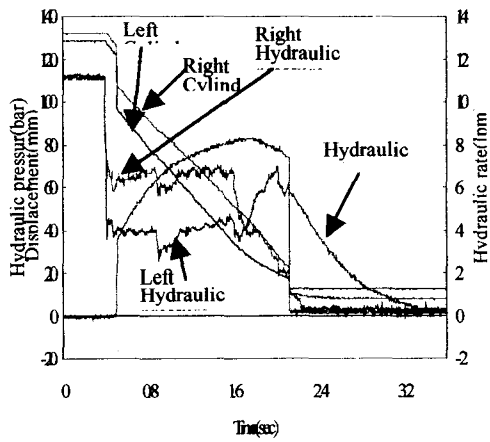
CONCLUSIONS

Automatic leveling control system was developed and system performance was measured and analyzed via indoor and field test. Kinematic displacement was investigated for the hydraulic system design through mechanism modeling. Results of up/down motion test showed that orifice diameter 1.4mm and flow rate 6.0*lpm* gave optimum performance. Downward motion test showed the control time difference caused by the unbalance of the left and right cylinder force. Dead band was 0.3°.

Step response showed time delay with orifice diameter of 1.4mm was 0.25sec. Settling time was about 7.5sec for the left cylinder and about 4secfor the right cylinder. Orifice diameter over 1.5mm showed vibratory phenomenon and gave the inconsistent pulse control. Travel test with orifice diameter of 1.4mm showed stable control response.

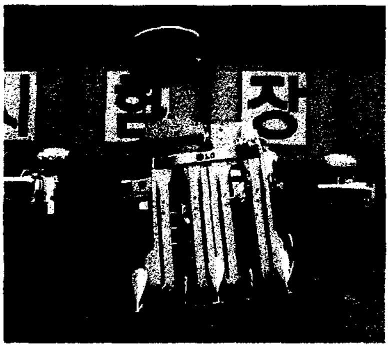


(a)Downward motion.

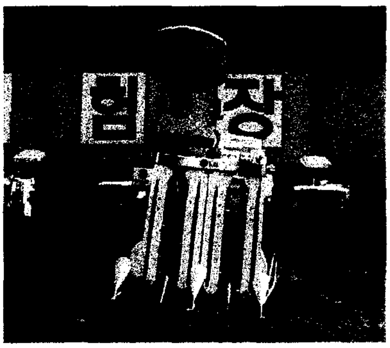


(b) Upward motion

Fig. 4 Response of the control unit at the 6*lpm* of flow rate.



(a) left control



(b) right control

Fig. 5 Combine used for the step response test in the laboratory.

(a) front view (b) rear view

Fig. 6 Step response test in the field.

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