AUTOMATIC BOOM HEIGHT CONTROL AND DESIGN PARAMETERS FOR HYDRAULIC DRIVES ON POTATO HARVESTERS

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Summary

An electrohydraulic automatic boom height control was designed and fabricated. The system was mounted on a Lockwood Mark 76 potato harvester and was tested for correct function of the automatic height control operating both independently from and simultaneously with manual control of the boom height. Design data for a variable speed hydraulic drive system on the harvester were collected while running the boom elevator and side elevator at different speeds for several simulated yields of potatoes. The maximum input power required for running a conveyor at a speed of 3 km/h under a potato yield of 37 t/ha was 2.43 kw. The required running torque was 108 N.m with a starting torque of 203 N.m The corresponding hydraulic oil pressures were 3.04 MPa for running and 5.78 MPa for starting. Maximum oil flow for each motor was 36 L/min.

1. INTRODUCTION

The greatest source of loss to potato growers has been found to be mechanical damage to tubers. The harvester is a major source of the potato damage (Townsend [1]). The boom elevator on the potato harvesters elevates and delivers the potatoes into a bulk transport vehicle. The height of fall of the potatoes is generally too great to handle the potatoes without damage. The operator of the present potato harvesters spends from 50 to 75 percent of his time operating the boom while he is digging (Johnson et al. [2]). This often leaves too little time to attend to the operation of the machine. As a result more potatoes than necessary could be damaged because of improper machine operation. An automatic boom height control can help maintain proper drop heights during loading of the truck and thus reduce potato damage.

A considerable reduction in mechanical damage to potatoes can be achieved by coordinating various conveyor speeds on the harvester with the forward speed and potato yield (Peterson et al [3]). Speed adjustment of the conveyors can be achieved using a variable speed-hydraulic drive system. Design data for hydraulic drives would help interested farmers and manufacturers to incorporate this system on the potato harvesters.

The objectives of this research were to

(i) Design, fabricate and test a low cost electro-hydraulic boom height control, and to

(ii) Obtain actual design data for the variable speed hydraulic drive system.

2. MATERIALS AND METHODS

2.1. Automatic boom height control

The automatic boom height control system designed for this study was a combination of mechanical, electronic and hydraulic components. A mechanical height sensor attached to the discharging end of the outer boom determined the height of the free fall of the tubers. When the sensor touched the bottom of the truck box or the top of the potato pile, the microswitch on the sensor actuated the electronic circuit which in turn operated the electrohydraulic valve.

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With the miscroswitch closed, current passed to the double-solenoid hydraulic valve. The valve directed hydraulic oil to a lift cylinder which lifted the boom. Lifting continued for an adjustable time interval. After the adjusted time interval the circuit switched the solenoid valve to the down position. The boom continued to cycle up and down through a distance which depended on the setting of the time delay and the flow of oil rate from the tractor hydraulic supply.

The electrohydraulic valve was a tandem centre, 3 – position double solenoid valve. The final electronic circuit is illustrated in Fig. 1. The electronic circuit control box was located near the operator's station on the tractor so that it could be reached for adjustments.

A variable speed rotating eccentric was built and used as a sinusoidal input to the height sensors. The sinusoidal input model represented the potato pile. The operation of the boom was observed for correct function of the automatic height control both independently from and simulatenously with manual control of the boom height.

2.2 Variable speed hydraulic drives

Design data were collected for two separate variable speed hydraulic motors driving the conveyors on the potato harvester. The side elevator and the rear cross conveyors were driven by one motor. Another hydraulic motor (Boom motor) drove the boom elevator. Both these motors ran in parallel and directly or indirectly drove the head shafts of the conveyors. The motors were supplied with hydraulic oil from the tractor hydraulic system. The specifications for the hydraulic motors of the drive system are given in Table 1.

A Flo-tech hydraulic tester was used to determine the oil flow and pressure for different loadings on the elevators. Sandbags were used to simulate net conveyor loads that would be expected for potato yield of zero to 44t/ha. The required starting torques for each simulated yield were also determined.

3. RESULTS AND DISCUSSION

3.1. Automatic boom height control

The automatic boom height control was mounted on a potato harvester. The system was first checked for correct function independent from the manual boom control. An input simulation model was built to represent the potato pile and was placed under the discharging end of the boom.

It was discovered that the time delays were not set correctly for the first tests. It was quickly determined that no delay was needed in either the lifting circuit or in the lowering circuit. There were some vibration problems associated with the sensors and the microswitches. Redesign of the sensor mounting overcame these problems. The available oil flow for downward travel of the boom was excessive. Flow control valves to the outer boom lift cylinders overcame this problem.

The above modifications gave satisfactory operation in the fully automatic mode. Safety considerations and field practice considerations made it imperative to provide a manual control over-ride. The manual over-ride control did not work satisfactorily. The problem was traced to the internal hydraulic system of the tractor used as the power unit.

3.2 Hydraulic drive design data

The results of power and torque measurements for the side and boom elevators are listed in Table 2 and 3, respectively. The maximum power required was for the boom elevator motor at the maximum simulated yield of 37t/ha. The power was 1.13 kW at an oil flow of 22 L/min and an oil pressure of 3.04MPa. The maximum power for the side elevator motor was 0.89 kW at an oil flow of 20L/min and an oil pressure of 2.75MPa when the simulate yield was 44/ha.

There is the possibility of running the conveyors at the same speed as the average field speed of 3 km/h. A linear relationship was determined for the data of Table 3 with increasing conveyor speed. For an assumed maximum yield of 37t/ha the required power would be 2.43 kW at an oil flow of 36L/min.

4. CONCLUSIONS

(i) The automatic boom height control performed satisfactorily when operated independently from the manual control. The manual over-ride control did not work satisfactorily because of some internal problems in the hydraulic system of the tractor used as a power unit.

(ii) For conveyor speeds equal to the average field speed of 3 km/h the boom elevator motor would require 2.43 kW at an oil flow of 36 L/min for a potato yield of 37t/ha.

(iii) At the maximum yield simulated in this study, starting torques were 203 N.m for the boom elevator and 108 N.m for the side elevator motor. The required maximum oil pressure would be 5.78MPa.

ACKNOWLEDGEMENTS

The authors wish to acknowledge with gratitude the support of the University of Ife, Nigeria and the University of Manitoba, Canada.

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Table 1. Specifications for the Hydraulic Motors

Specification	Boom Elevator Motor	Side Elevator Motor
Model	Charlyn M—206	Charlyn M—204
Displacement, L/rev	0.244	0.169
Maximum flow capacity, L/min	56.8	56.8
Maximum speed at maximum flow, rev/min	233	336
Maximum pressure, MPa	6.89	8.27
Maximum torque, N.m	120	166

Table 2. Hydraulic Requirements for a Hydraulic Motor to Drive the Side Elevator on a Potato Harvester

Conveyor Loading (Simulated Yield) (t/ha)	Starting Torque (N.m)	Conveyor Speed (km/h)	Motor Speed (rev/min)	Oil Flow (L/min)	Oil Pressure (Mpa)	Hydraulic Power (kW)	Running Torque (N.m)*
0	(68)	1.75	85	15	0.88	0.22	22
		2.25	110	20	1.77	0.58	45
11	(75)	1.75	85	15	1.08	0.26	27
		2.25	110	20	1.77	0.58	45
17	(77)	1.75	85	15	1.18	0.29	29
		2.25	110	20	1.86	0.60	47
22	(81)	1.75	85	15	1.27	0.31	31
		2.25	110	20	1.96	0.64	50
33	(95)	1.75	85	15	1.47	0.36	36
		2.25	110	20	2.26	0.73	58
44	(108)	1.75	85	15	1.86	0.46	46
		2.25	110	20	2.75	0.89	70

*Ninety percent efficiency assumed.

Table 3. Hydraulic Requirements for a Hydraulic Motor to Drive the Boom Elevator on a Potato Harvester

Conveyor Loading (Simulated Yield) (t/ha)	Starting Torque (N.m)	Conveyor Speed (km/h)	Motor Speed (rev/min)	Oil Flow (L/min)	Oil Pressure (MPa)	Hydraulic Power (KW)	Running Torque (N.m)*
0	(163)	1.36	66	16	0.98	0.27	35
		1.85	90	22	1.96	0.73	70
9	(170)	1.36	66	16	1.18	0.32	42
		1.85	90	22	1.96	0.73	70
14	(176)	1.36	66	16	1.27	0.35	45
		1.85	90	22	2.21	0.83	79
18	(179)	1.36	66	16	1.47	0.40	52
		1.85	90	22	2.35	0.88	84
26	(190)	1.36	66	16	1.67	0.45	59
		1.85	90	22	2.70	1.01	96
37	(203)	1.36	66	16	1.96	0.53	69
		1.85	90	22	3.04	1.13	108

*Ninety percent efficiency assumed.

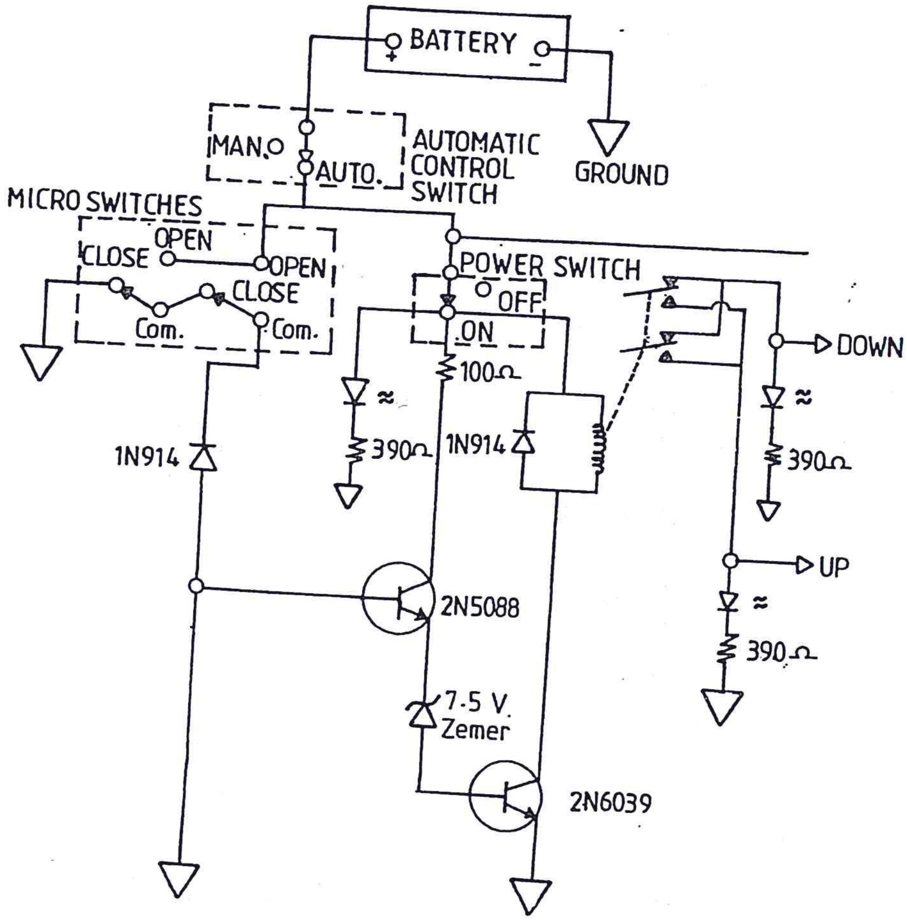

Fig. 1 Final Electronic Circuit for Automatic Boom Height Control

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2. MORRIS, J.E. and GEWARTOWSKI, J.W. "A 1W 6Ghz IMPATT Amplifier For Short Haul Radio Applications", Proceedings of the IEEE International Conference on Communication, Washington D.C., 1973, Vol. 1 pp. 8-27.
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