AUTOMATIC DEPTH CONTROL FOR A DISCER

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INTRODUCTION

Most tillage implements used on farms in Western Canada are of the trailing type. Depth of tillage is controlled from the tractor by manually operating valves that actuate hydraulic cylinders. The discer is one of these implements, and is used for both tillage and seeding. The depth of tillage of the discer under manual control varies considerably. Harrison (3) reported a depth variation of ± 1.0 inch (2.5 cm) at a single depth setting of the implement, while Friesen (1) reported that variations of ± 0.5 inch (1.27 cm) to ± 1.5 inches (3.8 cm) may be experienced. Observations made at the Research Station, Swift Current, Saskatchewan showed that variations in the operating depth of up to ± 1.75 inches (4.45 cm) were not unusual when tilling a stubble field. The effect of depth variation on power requirements has also been noted (4). It is further suspected that uneven seed placement by this machine may result in uneven germination and possible reduced yields.

Efforts to regulate the depth of a discer by manually manipulating the control valve are limited by the inability of the operator to estimate the depth of tillage. Current practice of tandem hitching several implements (Figure 1) makes it extremely difficult for the operator to estimate the depth of the rear furrow as much as 75 ft (22.5 m) away which is totally or partially obscured by dust.

This paper describes the development of a simple automatic control system to maintain a uniform tillage depth on a discer. The performance of this system during field testing is discussed.

INSTRUMENTATION

The tillage depth is defined as the distance from the furrow bottom to the soil surface. The soil surface is normally lumpy and somewhat uneven which complicates depth measurements to some extent. A transducer (Figures 2 and 3) was developed to measure the depth and served as an essential part of the control system and the data recording system.

The design incorporates some of the features of transducers devised by other researchers (2, 4). The ski [1 ft (30.5 cm) wide] and the gauge wheel [6 inches (15.2 cm) wide] provide a ground level reference, while the disc itself senses the furrow bottom. For depths from 0 to 5 inches (12.7 cm) the angle θ (Figures 2 and 3) is linearly proportional to the working depth. A single-turn potentiometer is mounted on the member connected to the front ski. A spring-tensioned cable wound around the potentiometer shaft is connected to the rear gauge wheel member. Thus, as the depth of the disc varies, the potentiometer rotates, giving a signal proportional to the furrow depth. The signal is amplified and recorded on a Brush oscillograph (Figure 4).

The transducer was calibrated on a level floor by placing blocks of various thicknesses under the ski and gauge wheel while the disc gang rested on the floor.

THE CONTROL SYSTEM

The main requirements of a control system are: (1) low cost; (2) simplicity to enable farmer servicing; and (3) ability to control the depth to ±0.375 inch (0.95 cm) at field speeds of up to 6 mph (9.6 km/h).

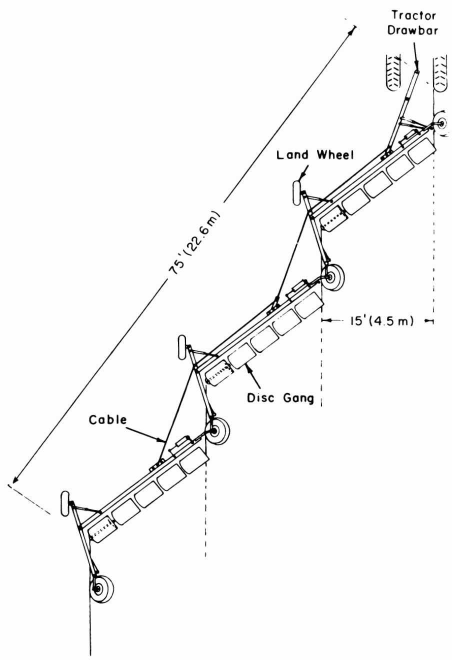

Figure 1. Tandem hitching of three discers.

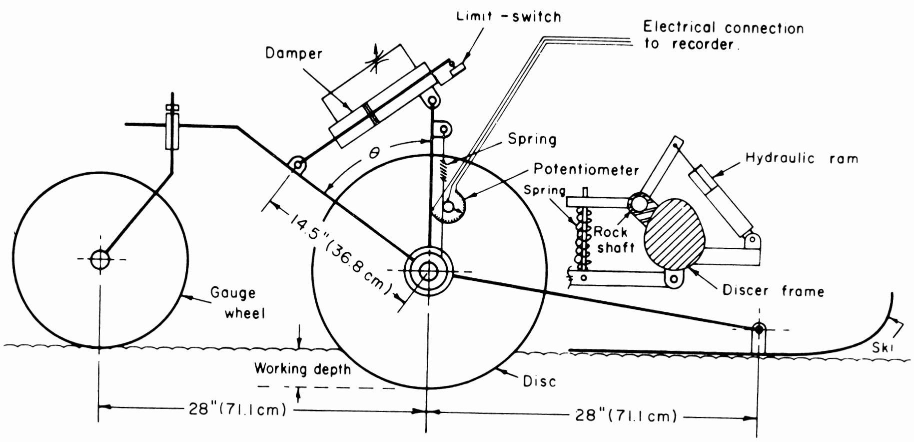

Figure 2. Schematic of the depth transducer for a discer.

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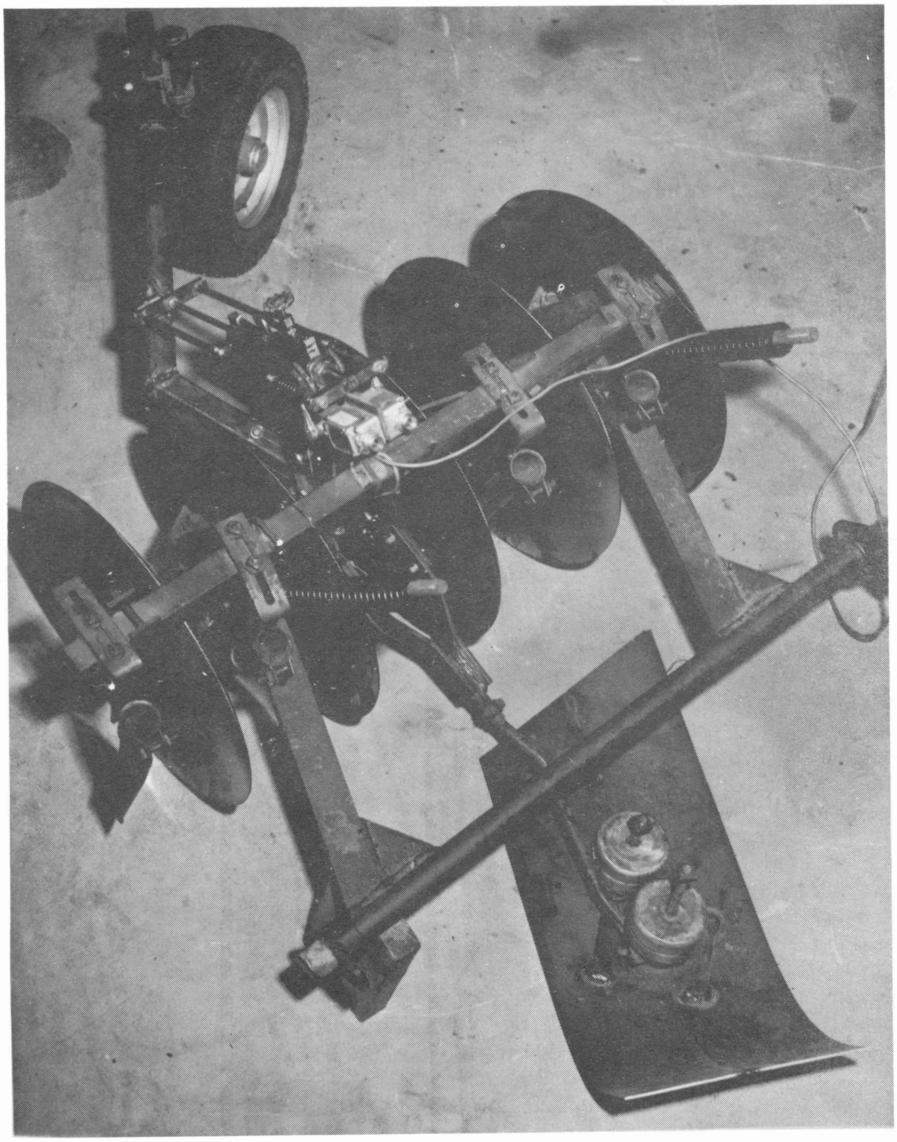

Figure 3. Depth transducer and disc gang removed from the discer.

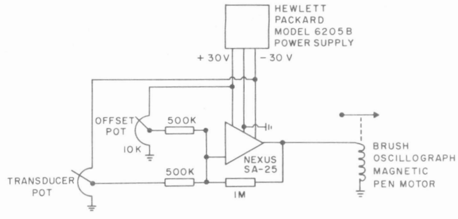

Figure 4. Instrumentation system for data collection.

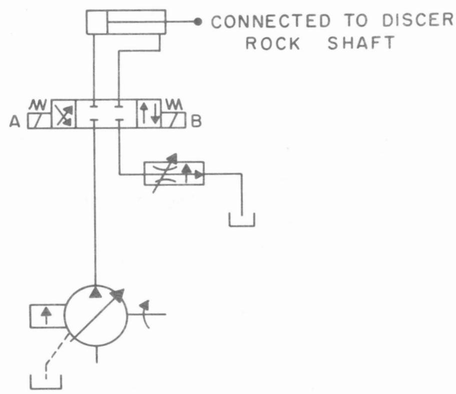

Figure 5. Hydraulic circuit.

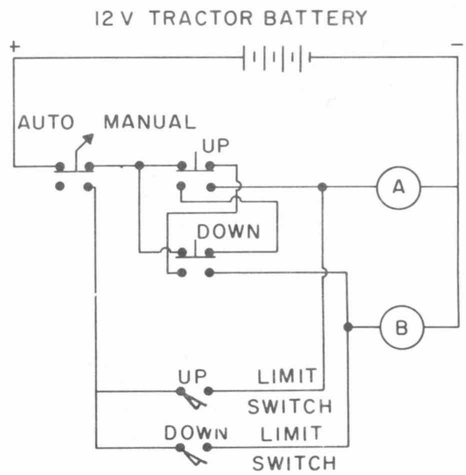

Figure 6. Control circuit.

In order to satisfy requirements 1 and 2, a simple on-off system was incorporated into the conventional tractor-implement hydraulic system. A tractor with a constant pressure, variable displacement pump (Figure 5) was selected to enable adjustment of flow rate or system gain with a pressure compensated flow control valve. The flow control valve was placed in the return line giving a meter-out system to ensure control of cylinder speed regardless of the direction of the load.

Figure 6 illustrates the control circuit. The auto-manual selector switch permits the operator to switch to manual control in extremely rough areas of the field and to raise and lower the implement. In the auto position, cam-operated limit switches mounted on the damping cylinder (Figures 5, 2 and 3) control the solenoid valve. The ratio of the damping cylinder motion to the furrow depth is linear. The cams are adjusted to correspond to a given depth (set point) plus and minus a dead zone.

The damping device is necessary to eliminate actuation of the limit switches by the fluctuations caused by normal bumpy field conditions. The damping rate can be varied by adjusting a needle valve which restricts the flow of oil from one end of the cylinder to the other. Trace 1 in Figure 7 illustrates the transducer signal with the needle valve wide open (minimum damping). Points (a) and (b) illustrate the drastic fluctuation caused by normal field conditions with little real change in the mean depth. These extremes would have actuated the control system when control action was not necessary. Trace 2 illustrates the transducer signal when the needle valve had been adjusted to heavily dampen the signal. The fluctuations were reduced and the mean depth was recorded. Thus, the control system is actuated only when a significant change in depth occurs.

EXPERIMENTAL PROCEDURE AND RESULTS

Tests were conducted in June, 1968 on a stubble field that had not been cultivated since the spring of 1967. The soil was not uniformly firm and therefore presented a severe test for the control system. The field speed for the tests was 3.5 mph (5.6 km/h). The cams on the depth transducer were set at 2.82 inches (7.16 cm) ±0.25 inch (0.63 cm). This

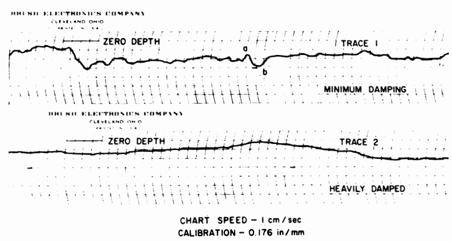

Figure 7. Oscillograph traces of depth transducer signal.

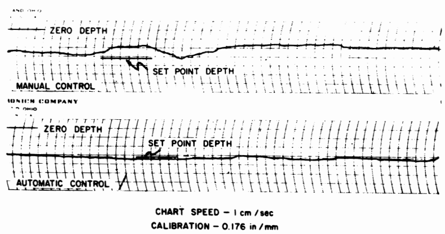

Figure 8. Oscillograph traces from Test No. 2.

TABLE I DEPTH DATA FOR DISCER TESTS (SET POINT DEPTH = 2.82 INCHES)

Test	Control mode	Mean depth (inches)	Mean error (inches)	Maximum† error (inches)
I	Manual	3.76	+0.94	+1.76 and −0.35
	Automatic	3.05	+0.23	+0.35 and −0.35
II	Manual	3.66	−0.84	−1.40
	Automatic	3.00	+0.18	+0.18 and −0.18
III	Manual	1.95	−0.86	+0.53 and −1.76
	Automatic	2.98	+0.16	+0.35 and −0.26
IV	Manual	2.38	−0.44	+1.23
	Automatic	2.94	+0.12	+0.35 and −0.26

† Maximum positive and negative error of the oscillograph trace from the set point.

corresponds to 16 mm on the oscillograph chart. A series of successive runs of manual and automatic control was conducted, and the transducer signal recorded. On manual control the operator did not attempt to regulate the depth, but simply left the cylinder set at the position which corresponded to the set point when on automatic control.

The transducer calibration was checked by measuring the furrow depth manually when the depth was controlled automatically. These manual measurements fell within the limits of extreme recorded on the corresponding oscillograph chart.

For a number of these tests the areas under the oscillograph traces were integrated with a planimeter and means computed for a chart distance of 25 cm; this corresponds to a field distance of approximately 125 ft (38.1 m). The maximum error from the set point was noted also. The oscillograph traces of a typical run are illustrated by Figure 8; the results are tabulated in Table 1. The following statements summarize the results:

(1) On manual control the mean depth varied considerably from the set point, and maximum errors of 1 to 1.75 inches (2.5-4.5 cm) were frequently observed.

(2) The automatic control system reduced the mean error to less than ± 0.25 inch (0.63 cm) with maximum errors of ± 0.35 inch (0.89 cm).

DISCUSSION

The control system tested met requirements 1 and 2 and partially met requirement 3. Data obtained from tests at higher field speeds were not conclusive; however, they indicated that the control system as adjusted for the tests was not able to control the depth to the desired limits. One of the limitations of the system is the heavy damping in the feedback loop. This limits the system gain for stable operation and, hence, the performance. With further analysis and development, it is thought that the performance of the present system can be improved.

The depth transducer is subject to error if the field is badly ridged or dead furrows are present. However, since the depth measurement is continuous, it is suggested that the proportion of the readings that indicates the true depth will be statistically significant. This is based on the work of Harrison (3) and Harrison and Read (4) reporting on the performance of a similar transducer. It would be desirable to sense the depth over the entire width of the machine, but such a system would probably be more complex and expensive.

SUMMARY AND CONCLUSION

Preliminary field tests showed that the tillage depth of a discer under manual control varies up to ± 1.75 inches (4.45 cm). A depth transducer employing a gauge wheel, ski and disc gang was developed to measure the tillage depth. The control system consists of cam-actuated limit switches mounted on the depth transducer which control a solenoid operated hydraulic valve in the conventional tractor-implement hydraulic system. This system was field-tested and depth variations were limited to ± 0.35 inch (0.89 cm) at field speeds of 3.5 mph (5.9 km/h).

At moderate field speeds the performance of a discer can be considerably improved by use of a simple economical control system. Further development is necessary to improve the control at higher field speeds.

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