HYDRAULIC SENSING FOR HEIGHT CONTROL OF 'GROUND-FOLLOWING' BASE CUTTERS ON MECHANICAL CANE CUTTERS

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Abstract

As field microtopography can vary it is advisable to have automatic base cutters that will react to an obstacle or a sudden change in ground height. 'Ground-following' base cutters, which automatically follow the ground profile, are necessary for the machine to achieve its full potential. The use of hydraulics for an immediate response when encountering an obstacle was tried some years ago. The system automatically raised the base cutter when it came into contact with an obstruction, but a manual override was required to return the cutter to ground level. This manual control caused uneven base cutting, which resulted in excessive stubble being left in the field. Fully automatic 'ground-following' base cutters have been developed by using a hydraulic cylinder as an accumulator, charged by a continuous back-pressure of oil which links the base cutter motor to its lifting ram. The application of this principle to various machines and its use under different conditions is explained.

Introduction

In the mechanical harvesting of sugarcane, the height of basecutting has traditionally been regulated manually by observing a marker to indicate the predetermined cutting height, with manual control to avoid obstructions or to raise the base cutters if they should dig into the ground. To prevent the jamming of the base cutters when a mound of soil or an obstruction was encountered, more powerful engines and hydraulic drives were necessary. In order to be able to use machines of low engine power automatic control became necessary, especially when the base cutters were mounted in positions where the effect of undulating topography was amplified.

One approach is to use electronic equipment for sensing and controlling the height of the base cutters but this was considered too costly and impractical. While cutting is taking place, a hydraulic base cutter motor must meet varying power (torque) demands, caused by cutting at different heights and speeds, or due to the crop being lighter or heavier. Sudden obstructions require large increases in power to prevent the base cutters from stalling. This variation in power demand is accommodated by the continual variable pressure of the hydraulic oil supplied to the base cutter motor.

In 1978, van der Merwe *et al*[1] connected the oil pressure supply operating the base cutter to the assembly lifting ram in an attempt to provide automatic base cutter reaction to sudden obstructions. However, because the oil had to be fed through a relief valve, a manual override was necessary to return the base cutter to the normal operating position. This was impractical because the main oil supply to the base cutter became depleted, so the method was temporarily abandoned.

Further tests with a number of new cane cutting machines and harvesters have provided the equipment which was needed to develop the automatic height control for the base cutters. The method of height control involves the use of direct hydraulic pressure from the base cutter motor to raise the base cutter, and another pressure source to lower the base cutter when a reduction in pressure to the motor occurs.

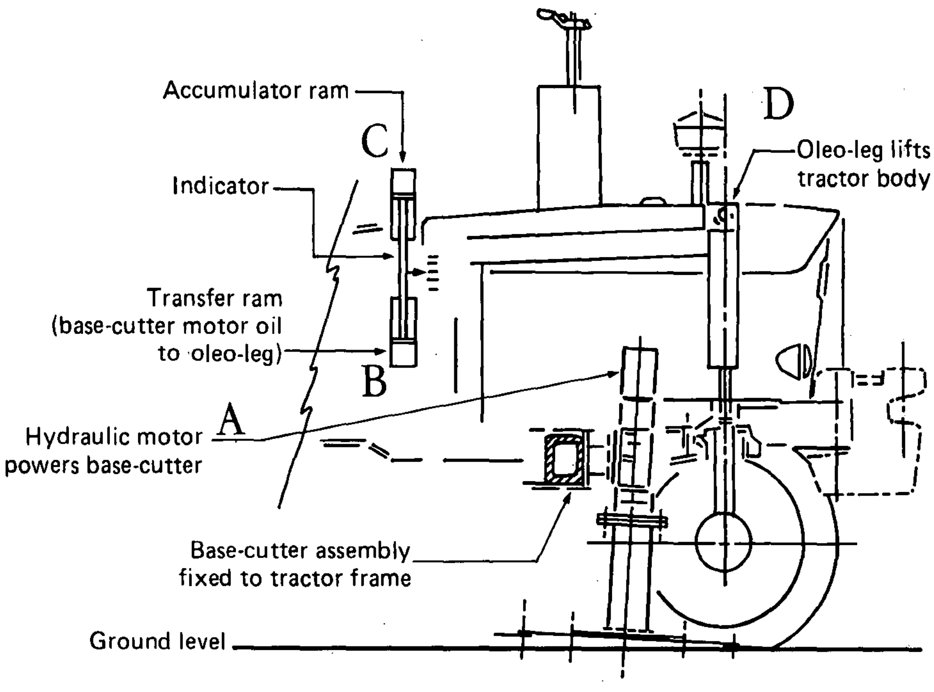

FIGURE 1 Base cutter assembly showing oleo-leg suspension.

Methods

It was established that when a base cutter operated at ground level, at a forward speed of 3 km h^{-1}, in cane yielding 80 tc ha^{-1}, on heavy soils, the particular base cutter motor in use required 5 MPa of oil pressure. An increase in the forward speed increased the pressure to the motor to more than 5 MPa. On the other hand, under similar conditions but on sandy soils, the base cutter dug into the ground by as much as 40 mm before the pressure to the motor increased to more than 5MPa. In this instance, if the automatic base cutter height control was set to operate at 5 MPa, an increase in speed was required for cutting to continue at ground level. Any further increase in the forward speed increased the pressure required to more than 5 MPa, causing the base cutter to lift and excess stubble to be left.

Based on this experience it was decided that a pressure varying between 5 and 7 MPa would be adequate for automatic base cutter height control under most conditions.

Shock-pressures exceeding 7 MPa occurred when the base cutter suddenly encountered large obstacles and a slow response in raising the base cutters under these conditions resulted in either the uprooting of the cane stools or jamming of the cutters. A relief valve set at 7 MPa was therefore fitted to relieve the excessive pressure caused by the shock-loads resulting in a very quick response in raising the base cutter clear of the obstruction. These pressures refer to a hydraulic circuit supplying oil to a hydraulic ram with a 50 mm piston diameter.

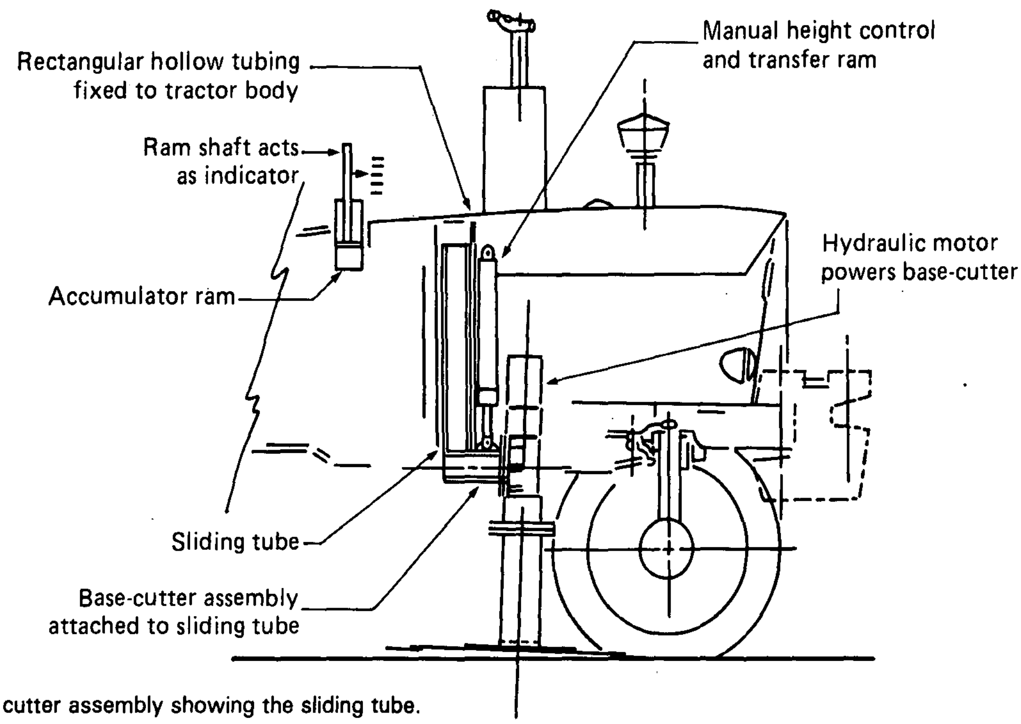

FIGURE 2 Base cutter assembly showing the sliding tube.

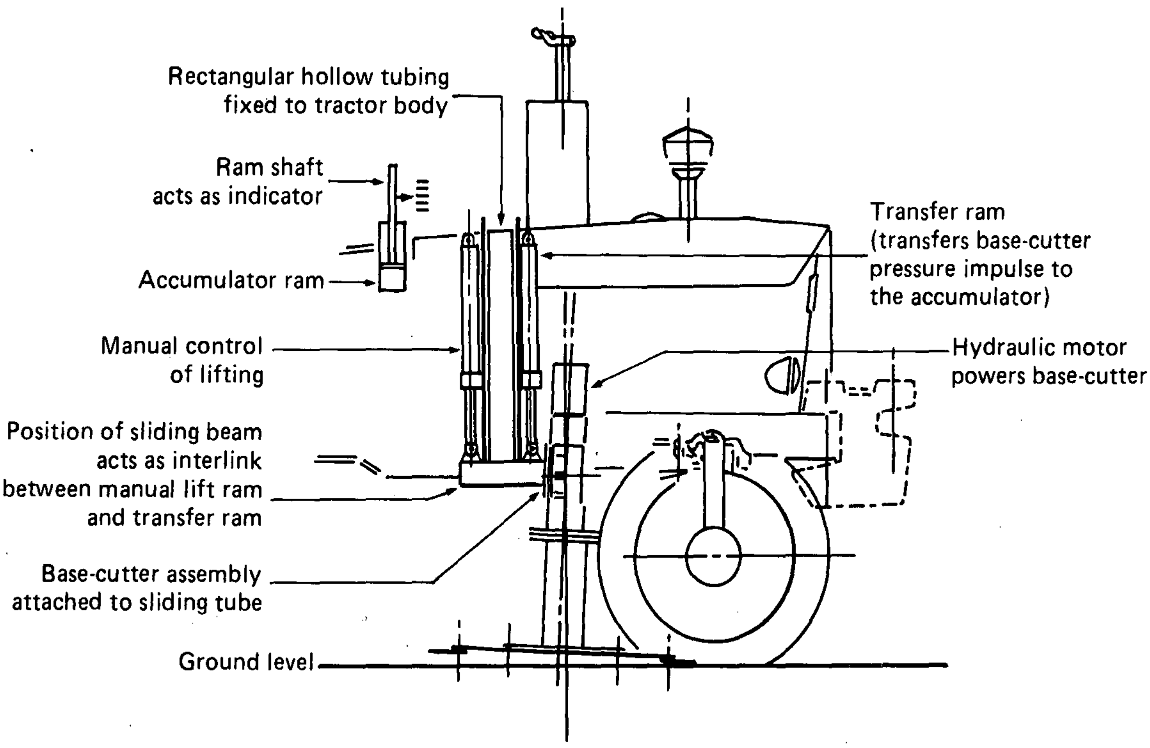

FIGURE 3 Base cutter assembly showing linked rams.

Methods of mounting base cutters on machines

Base cutter height control depends on how the assembly is attached to the machine and two methods can be used.

Method 1: the base cutter assembly is fixed to the main frame of the machine while the front wheels are attached by oleo-legs, or some other suspension frame with a hydraulic ram. The raising and lowering of the machine and the base cutter are controlled by moving the front wheels up or down hydraulically (see Figure 1).

Method 2: the body and front suspension are the same as those on a conventional tractor, and the base cutter assembly is attached to the tractor by a sliding sub-frame which is raised or lowered hydraulically (see Figures 2 and 3).

Description of automatic height control

Method 1: raising the entire frame so that the machine weight can be used to return the base cutter to ground level after auto-lift requires a pressure of 7 MPa in the lifting rams (oleo-legs) (Figure 1). The normal cutting pressure of 5 MPa is not sufficient to maintain a constant height of the machine above the ground level and a form of accumulator is required to provide the additional 2 MPa to the lifting rams.

Figure 4 shows that some of the oil driving the base cutter motor 'A' is by-passed into a transfer ram 'B', against the full bore of the piston. The oil on the other side of the piston is connected to the manual lift control line. The pressure of 5 MPa at 'B' is insufficient to carry the machine, and if this alone were transferred to 'D' the base cutter would dig into the ground.

To assist the lifting force generated by the base cutter motor when cutting at ground level, an accumulator ram 'C' is connected mechanically to the transfer ram 'B' and a constant, pre-set pressure is fed into 'C' against the annular face of the piston. The combined forces generated in rams 'B' and 'C' create a pressure of 7 MPa in 'D' to maintain equilibrium between the pressure required to raise the machine and the normal pressure generated by the base cutter motor while cutting.

The accumulator ram 'C' acts as a constantly charged pressure accumulator and receives its oil from a separate source which is regulated. Figure 4 shows the separate source from the hydraulic pump 'E', which supplies oil for the services (rams and other auxiliary items). An adjustable flow restrictor 'F' is used to generate the constant pressure required at 'C'. Depending on the mass of the machine and utilising the different piston areas of a ram, a suitable ram can either be selected or made to assist in the raising of the base cutter. This ram also serves as an indicator for the operator to observe base cutting height (see Figure 1).

Method 2: Figure 5 shows the hydraulic circuit when the base cutter assembly is attached to a sliding tube assembly which provides the raising and lowering motion. The hydraulic pumps 'H' are pto-driven and draw their oil from a common external reservoir 'I'. One pump supplies oil to the services while the other pump supplies the base cutter motors. Because there is only one hydraulic oil reservoir, the 'transfer' ram is replaced by a close/open valve 'B' to provide a manual override when the base cutter is not operating during the turning of the tractor and travelling to and from fields. A pressure of 1 MPa is needed to raise the 200 kg base cutter assembly. However, for cutting a pressure of 5 MPa is normally required. To balance these two pressures, the accumulator 'C' is connected hydraulically to ram 'D' and the oil trapped between 'D' and 'C' activates accumulator ram 'C'. The oil on the annular side of 'C is forced back into the system through the restrictor 'F'. Sudden overloads displace the accumulator piston too quickly and the oil is then dispersed through the pressure relief valve at 'E' which is set to function at 7 MPa. When the base cutter pressure drops the accumulator is recharged and the cutter is forced back to ground level by the oil pressure through the hydraulic link between 'C' and 'D'.

Figure 3 shows a variation of Method 2 in which two rams act on the sliding beam of the base cutter assembly. The open/close valve 'B' was replaced by the transfer ram 'B' which transfers the pressure from the base cutter to the lifting ram 'D' by a mechanical link (Figure 6). The action between the lifting ram and the accumulator is the same as described in Figure 5, although a different method of charging the accumulator is used. The oil flow is controlled by an adjustable flow regulator 'R' after it has passed through the valve at 'G'. By increasing the flow of oil to the fan motor 'K' the back pressure increases which charges the accumulator 'C'. This variation has the following advantages:

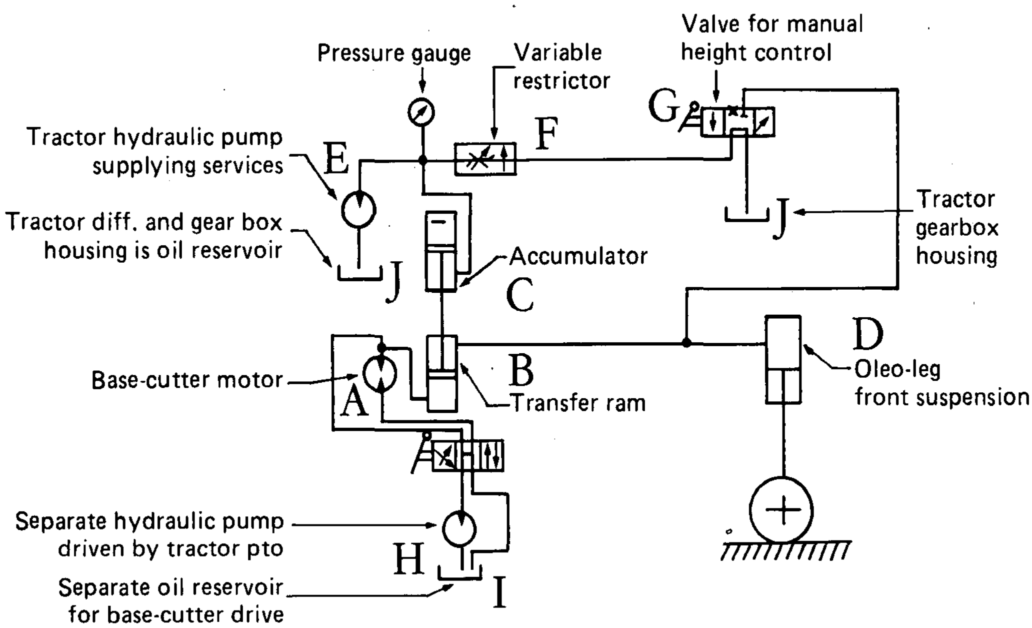

FIGURE 4 Hydraulic circuit diagram for Figure 1.

- charge pressure is provided by the back pressure which is created by the cooling fan motor. Under heavy cutting conditions an increase in the base cutting pressure achieved by resetting the adjustable regulator, will also increase the velocity of the fan and provide additional engine cooling
- there is manual override at all times and the open/close valve has been removed
- if oil for the base cutter motor and the services comes from two different reservoirs, mixing of oil is prevented, even if a piston seal should leak internally.

Results

When approaching the row of cane to be cut, the operator of the machine has to lower the base cutter until the accumulator ram rod moves approximately 25 mm from the zero position, indicating that the base cutter had made contact with the ground. Thereafter, the automatic 'ground-following' base cutters cut cane yielding from 25 to 120 tc ha^{-1} in light sandy to heavy clay soils. The maximum deviation of the cutting height caused by sudden changes in field conditions was from 20 mm above ground to 40 mm below ground, without any adjustment to accumulator charge pressure being necessary. However, if adjustments had been made, the deviation would have been less.

The constant pressure maintained at the base cutters prevents them from jamming, so the full engine power can be used to cut cane instead of having to overcome any extra resistance. An increase in output was therefore achieved in low yielding cane due to increased foward speeds.

Conclusion

A smoother utilization of power reduced wear on the machines and the ease of operation improved driver efficiency and resulted in less downtime. Additional components that are necessary for the automatic 'ground-following' base cutters are:

2 × 50 mm standard hydraulic rams
1 × adjustable flow regulator
1 × adjustable flow restrictor
1 × relief valve
1 × pressure gauge

These components can easily be obtained and fitted, they are simple to maintain and they are relatively inexpensive.

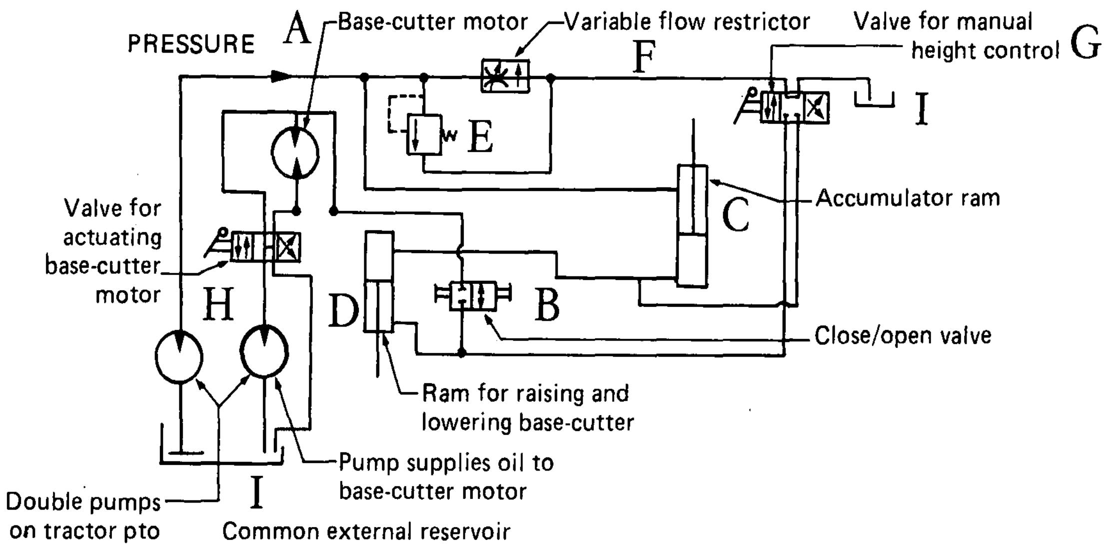

FIGURE 5 Hydraulic circuit diagram for Figure 2.

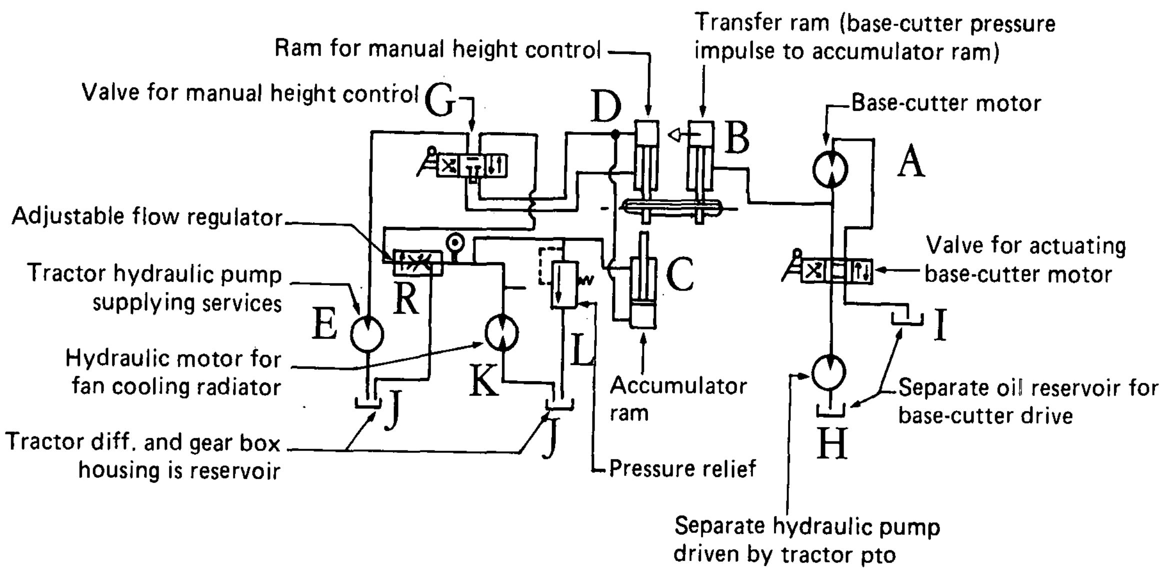

FIGURE 6 Hydraulic circuit diagram for Figure 3.

From the results it appears that, with further development, this hydraulic sensing system could be applied to increase the efficiency of most cane cutters and harvesters as well as other types of hydraulically-driven machinery.

Acknowledgements

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REFERENCE

1. Van der Merwe, G; Pilcher, J.R. and Meyer, E (1978). The Edgecombe cane cutter. *Proc. S. Afr. Sug. Technol. Ass.* 52: 169–173.