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THE SETTING AND CONTROL OF DISC PLOUGHS

By P. A. TAYLOR, Principal Research Scientist, Division of Mechanical Engineering, C.S.I.R.O.

THE trailed disc plough is the most commonly used tillage implement in Australian broad-acre farming, yet it is considered in some areas to be difficult to set and to operate. These notes provide information resulting from C.S.I.R.O. research to assist operators in the control and operation of trailed disc ploughs.

The various makes of plough available in Australia commonly had from 10 to 18 discs, each mounted on an arm with a stump-jump mechanism, though a few models were of the twin-disc type with two discs of unequal diameter mounted on one arm. To accommodate the ever increasing power of tractors over the past few years, the size of ploughs has increased and 22 or 24-disc models are already on the market; even larger sizes will be seen in the near future.

With the usual 22 and 24 in.-diameter discs, the maximum furrow width is between 7.5 and 8 in., giving widths of cut from 6 feet with a 10-disc plough, to 16 feet with 24 discs. The practical limitation on furrow width is the inter-furrow ridging.

Wheel arrangements and spacing vary widely between makes; the common features are that all have one front wheel running in the last furrow of the previous round, and one front wheel running on the unploughed land.

At the rear, the various arrangements include a single furrow wheel, two wheels abreast, or two smaller wheels in tandem. In the abreast arrangement one wheel runs in the furrow and the other on the land; the axis is free to rotate about a fore-and-aft axis. Two makes of plough have tandem rear wheels; one has both wheels in the furrow, the other has the forward wheel on the land and the rearmost one in the furrow.

As a disc is pulled through the ground, the soil acts to push it upwards out of the ground, sideways towards the unploughed land and rearwards to oppose its forward travel. Part of the plough weight keeps the discs in the ground, the wheels carry the rest of the weight and counteract the sideways soil forces on the discs, and the tractor overcomes the resistance to motion.

The wheels provide a steering force when angled to the direction of travel or when cambered; the magnitude of the steering force depends on the two angles and the weight carried, and naturally is far greater if the wheel is in a furrow. All the wheels should point slightly towards the ploughed land, at a drift angle between 5 and 10 deg.; many people do not realise that angles greater than about 12 or 15 deg. may actually reduce the steering action, though they certainly add to the drawbar pull and increase the wear of the tyres.

The position of the tractor is a matter of opinion or personal convenience. Some like to run it in the furrow with the drawbar angled to the plough, others prefer to run out on the land with the drawbar straight (or slightly angled). As ploughs get larger, it becomes more and more likely that the tractor has to be run out on the land. In either case, the setting and control are very similar.

Opening cut

There are various ways of making the initial cut. To lessen the amount of soil that can bank up by fences, some operators prefer to do the initial round with the rearmost disc cutting full depth and the depth of the others tapering off to zero at the front furrow wheel. This means that with the plough level the furrow wheels are raised until the discs just touch the ground, and the landwheel is then raised to a height equal to the desired
depth. This method saves adjusting the front furrow wheel on the second round, but it is difficult to control the depth of the rearmost disc, and of course the depth varies across the gang of discs.

Another way is to raise all the wheels to a height above ground equal to the desired depth, remove the last two or three discs, set the width to, say, 60 per cent, of the full width and plough. This method will give even depth because all the wheels run on the unploughed land, but requires adjustment of the front and rear furrow wheels for subsequent rounds.

Adjustments available and setting sequence

After the initial furrows have been cut and the wheel heights set correctly, the plough can be set for normal operation.

Some features and characteristics of a plough are fixed by the designer; others are adjustable and must be decided by the operator. For example, the operator can change the width of cut, the depth, wheel toe-in or drift angles, the lateral position and the height of the drawbar the amount of ballast and the speed.

He cannot change the tilt angle of the discs (except by such extreme measures as blocking the stamp-jump mechanism) or their angle of attack at any particular furrow width; these all have a large influence on the operating characteristics of a plough, but are fixed by the designer.

So the operator must decide setting for:

**Width and depth of cut**

In general, when ploughing on light soils, the plough can be set fully open, and on heavy or clayey soils it should be set initially at about two-thirds of full width. When properly adjusted, the resulting depth will depend on the width and the weight of the plough; this is dealt with in detail below.

**Wheel angles**

All the wheels can be set to toe-in towards the ploughed land at a small angle of say, 5 deg. initially.

**Drawbar location**

The drawbar should be parallel to the furrow, pointing initially at the centre of the gang of discs; its final position laterally will be found to be within 10 in. either side of this centre, depending on the make of plough. The centre of the gang is taken relative to the cutting edge of the discs; for an 18-disc plough, for example, if the drawbar is pointed at the bearing-cap of the ninth disc, it will be on a line approximately midway between the ninth and 10th discs. The drawbar height should be low to keep sufficient weight on the rear wheel; the reasons are given later.

**Corrections to settings**

Having made these settings and connected the drawbar, move forward and attempt ploughing. Some readjustment is bound to be necessary. The important point is to make one correction at a time.

The front and rear furrow wheels should run comfortably in the radius of the furrow. Correct positioning is essential for an even depth of cut across the gang of discs. If either wheel is well away from the furrow wall, then the first correction to be tried is to the lateral position of the drawbar. Suppose the rear wheel is crabbing onto the ploughed land and the front furrow wheel is riding up the wall; this situation can be corrected by moving the drawbar pivot towards the land wheel, not forgetting to adjust the steering link to the front wheel by the same amount.

Alternatively, when the first disc is not cutting properly because the front furrow wheel is running in the bottom of the furrow, and the rear wheel is trying to jump out, the drawbar should be removed towards the front furrow wheel. In short, lateral adjustment of the drawbar causes the rear wheel to move sideways in its furrow in the same direction, and the front furrow wheel to move in the opposite direction.

Another situation is when both wheels are running wrongly. If they are too far down in the furrow—

- Reduce their drift angles, or
- Open the plough to a wider cut, since the indication is that the wheels are carrying excessive weight.
If both wheels run too far up the furrow wall—

- Increase their drift angles, as long as they are not already greater than 10 deg., or
- Close the plough to a narrower width, or
- Add ballast to increase the weight.

The ballast in this case can be positioned along the beam or near both furrow wheels.

**Width and depth of cut**

For any plough, width and depth of cut are dependent on each other. In normal soil conditions, if the plough is closed up, the depth of ploughing will increase; on the first round, it will be found that the last furrow to be cut is considerably deeper than the one the front furrow wheel is running in, then on subsequent rounds the depth across the gang of discs will even out to some intermediate value. Similarly, when the plough is opened, the depth will decrease. In either case, because both width and depth change together, there will be very little difference in the drawbar pull required from the tractor. When the depth is held constant, then of course the drawbar pull changes with the width of cut.

The interdependence of width and depth may be difficult to appreciate for it is natural to think that the wheels of a trailed implement maintain a set depth; they do not when they run on the cultivated ground. The plough settles into a state of equilibrium and the depth is automatically varied to attain this state, just as a boat settles in the water to a depth to suit its weight.

The change in depth as the width is altered can be reduced by re-setting the drift angles of the furrow wheels: setting little or no drift angle when the plough is closed, and setting greater angles as the plough is opened. Alternatively, to maintain depth at a wider cut the weight can be altered by adding ballast, since it follows that the limiting factor to the width of cut is the weight of the plough.

At some stage as the plough is opened, it will be impossible to stop one of the furrow wheels jumping out of its furrow merely by moving the drawbar. Ballast must then be added or the width reduced; it is not economic to make ploughs heavy enough to cope with all soil conditions. The ballast should be added as near as possible to a line joining the furrow wheels, because weight transfer within the plough leaves insufficient weight on the furrow wheels and relatively too much on the land wheel. In practice this means placing ballast along the beam or adjacent to the furrow wheels. If it is added near the rear wheel, the drawbar may have to be shifted sideways towards the land wheel; similarly, if added near the front furrow wheel, the drawbar will have to be moved towards that wheel.

The amount of ballast required depends on the make of plough and soil conditions. On heavy clayey soils the ballast required to open the plough to a reasonable width may be 50 per cent, or more of the basic weight of the plough; on light soils, such as in the Mallee, only an additional 10 per cent of the basic weight may be needed to get the plough to full working width and depth.

In tough soil conditions, it will not be possible to open the plough to its maximum width. Penetration is the major problem, and is made easier when the plough is closed; the weight required to make the discs penetrate and stay in the ground rises very rapidly on clayey soils as the plough is opened up. Even with the plough closed, a considerable amount of ballast may be required. Under such conditions, the drawbar pull will also be high.

**Weight and drawbar height**

It is well known that the height of the hitchpoint between tractor and implement determines the amount of weight transferred from the front to the rear wheels of the tractor, and this is used to improve traction.

The lower the drawbar the less weight is transferred from the front to the rear wheels. Although lowering the drawbar causes a loss in efficiency there is a limit to the height to which the drawbar can be raised with safety. At a point below the height of the tractor's rear axle all the weight is transferred away from the front wheels—a highly dangerous situation.
In a similar manner, the height of the drawbar pivot on the plough affects the weight transfer from the rear to the front wheels. A high drawbar makes it easier for the rear furrow wheel to jump out (because it is left with little weight), and at the same time imposes high loads on the front wheels, particularly the land wheel. Because the land wheel cannot work as effectively as the furrow wheels, it needs more weight, so a high drawbar also means that the plough has to be heavier, particularly on lighter soils.

If the drawbar is not parallel to the ground, then again weight transfer between the front and the rear wheels of the plough is affected. Inclining it upwards to the tractor tends to increase the weight on the rear furrow wheel; inclining it downwards to the tractor tends to increase the weight on the front wheels of the plough.

The re-distribution of weight when the drawbar height is changed means that the drawbar must also be moved sideways: if the drawbar is raised or inclined down to the tractor, it must also be shifted towards the front furrow wheel; if lowered or inclined upwards to the tractor, the shift is towards the land wheel.

### Bouncing

Bouncing of ploughs is sometimes experienced in light soils. It results from either a resonance effect of the soil forces on the discs or a lack of stability arising from poor setting and operation; in practice, the latter cause is more usual. A plough can be made to bounce by operating at high speeds and widths of cut with insufficient weight. In such circumstances, the furrow wheels have to be set with a high drift angle and therefore operate in an unstable region; they do not have sufficient capacity to cope with fluctuations of the soil forces on the discs, and consequently the rear furrow wheel in particular is continually riding up the furrow wall until the disc forces decrease, then as the discs dig deeper it falls back into the furrow.

Bouncing can be overcome by operating at a lesser speed or by adding ballast and reducing the wheel angles; adding ballast also helps to raise the natural frequency of the plough and obviate resonance effects.

### Summary of setting and control adjustments

<table>
<thead>
<tr>
<th>Condition</th>
<th>Remedy</th>
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<tbody>
<tr>
<td>Lack of penetration</td>
<td>Add ballast to increase the weight, preferably behind the main beam and adjacent to the furrow wheels, or Reduce the width of cut</td>
</tr>
<tr>
<td>Depth of cut too great</td>
<td>Increase the width of cut</td>
</tr>
<tr>
<td>Insufficient width of cut obtainable</td>
<td>Add ballast as above</td>
</tr>
<tr>
<td>Front furrow wheel attempting to jump out</td>
<td>Move drawbar pivot towards land wheel, or Increase the drift angle to not more than 10 deg., or Add ballast near front furrow wheel</td>
</tr>
<tr>
<td>Rear furrow wheel attempting to jump out</td>
<td>Move drawbar pivot towards front furrow wheel, or Increase the drift angle, or Add ballast near rear furrow wheel, or Lower the drawbar</td>
</tr>
<tr>
<td>Front furrow wheel too far down in furrow and first disc cutting too small a slice</td>
<td>Move drawbar pivot towards front furrow wheel</td>
</tr>
<tr>
<td>Rear furrow wheel too far down in furrow</td>
<td>Move drawbar pivot towards land wheel, or Increase the width of cut</td>
</tr>
</tbody>
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