# Mechanics and Features of Disc Openers in Zero-Till Applications

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## THE CALL FOR DISC SEEDERS

The rising interest in many areas of Australia for 'zero-till' disc seeders is greatly driven by their low soil disturbance characteristic, which minimises weed seed germination, soil layer mixing, stubble incorporation and moisture dilution / evaporation at sowing. Additionally, their suitability to higher speed sowing (eg. with minimal soil throw) and ability to handle creeper weeds and crop residue without blockage are widely recognised.

**Fig. 1: V paired disc designs typically offer very accurate seed placement in non-sticky conditions. With one pass zero-till systems, they best operate in a triple coulter layout (eg. behind an additional deep working coulter disc offering deep soil disturbance, residue cutting and fertiliser banding benefits) –*Agrowdrill* – top - and *K-Hart* designs shown**

Disc seeders are often perceived to achieve superior seed placement quality (eg. V paired discs of the type shown in Fig. 1). However, this feature is not universal with all disc systems and seeding uniformity can greatly vary depending on i) design (eg. dual banding with single disc openers), ii) operation (eg. cutting depth, soil throw issues) and, iii) soil conditions (eg. sticky soils, soft/hard paddock areas).

A wide range of zero-till disc seeders is now available in Australia. The awareness of the machinery issues associated with design features and paddock operation of disc implements can assist farmers with making the right selection or improving the seeder performance in a farm context. The information provided in this article relied on outcomes and field observations under seeding system trials conducted by the AMRDC (GRDC / SAGIT funding) as well as research literature.

**Fig. 2: Swivel type, fertiliser banding and parallelogram mounted disc coulter – the ripples result in improved driving ability compared to smooth discs (eg. Yetter design shown)**

## SEEDER DISC GEOMETRIES

Zero-till disc openers may be classified into three design categories:

1. <u>Coulter disc:</u> flat or fluted disc types, continuous or scalloped cutting edge, free swivelling or rigid in the vertical plane and running parallel to the travel direction. Soil disturbance and soil throw in a given soil type and condition are function of disc attributes (eg. smooth, bubble, ripple or wavy) and settings (eg. cutting depth and operating speed). No side forces are generated and common disc

diameters range between 17" and 20". Coulter disc applications include deep soil disturbance, residue cutting and seed/fertiliser banding (eg. see Fig. 2), sometimes in association with tine and point openers.

**Fig. 3: Angled disc openers develop side forces and are associated with a side wheel, which may have some or all of the following functions: soil throw control, disc cleaning, depth gauge and furrow closing. Its position and orientation relative to the disc influences disc cleaning ability and can affect draft requirements. (eg. Milne industries *Day-Break* design shown)**

2. Angled disc: single disc unit, mostly flat smooth type, set vertically but running at a small angle of sweep (eg. 5-8 deg.) to the travel direction. The sweep angle allows seed/fertiliser delivery boot(s) to be located in the 'shadow' of the disc (passive side). Soil disturbance is function of sweep angle, cutting depth and disc diameter. Side forces are generated, which must be balanced between left and right handed units, at best on each rank of an implement. Common disc diameters range between 17" and 24" (eg. see Fig. 3)
3. Undercut disc: a similar flat smooth discs disc tilted sideways from the vertical (up to 20 deg.) in addition to a similar sweep angle (NB: relative soil disturbance may be increased, side forces still apply – eg. Fig. 4). Due to the tilt angle, the shadow of the undercut disc can be increased by running the implement frame lower with the disc opener regulated by the depth wheel. Undercut discs are often paired in opposition (eg. closed in at front - Fig. 1 or opened up at front - Fig. 9) as a means to cancel side forces. Closed-in paired disc configurations present the highest risks of smearing and furrow compaction, and are best used behind deeper working coulters (eg. triple coulter set-up) to minimise down pressure requirements, and therefore compaction damage.

## DISC DRAFT REQUIREMENTS

Essentially, a coulter disc can be compared to a very narrow point inclined at a backward rake angle, where the additional rotating motion imparts a slightly different balance in soil-tool force reactions. Because of the backward rake angle feature, vertical up force reactions increase very drastically with cutting depth.

Disc thickness and wedge angle (see basic coulter disc geometry summarised in Fig. 5) are critical factors influencing the disc operating forces, whereby thin discs and small wedge angle minimise both draft and vertical force reactions, but are subject to shorter wear life, lower strength and poorer durability.

As the disc develops a blunt cutting edge, both vertical and draft force reactions quickly increase, together with a reducing ability to cut through residues. Higher forward speeds may improve the residue cutting ability of coulter discs.

The draft force reaction of a coulter disc is typically proportional to the weight required to keep the disc at to the desired cutting depth, which in turn is proportional to disc diameter (ie. path length of contact area in the front quarter of the disc – Fig. 5). Draft forces are expected to greatly increase with bigger sweep angles and smaller tilt angles, and significant penalty would occur due to the presence of a cleaner wheel, creating a surcharging effect function of its bearing weight.

Draft measurement in sandy and clay-loam soils show coulter disc systems can potentially require significantly greater draft (by up to 40%) relative to a point system at similar operating depth. The draft penalty is pronounced in harder soil conditions, being driven by high weight loadings required to successfully operate at the reference depth, and can disappear in softer soil conditions. Draft measurements with angled and undercut disc systems showed even greater draft penalties. These results may not always correlate with main stream farmer experience or commercial claims, as comparative ratings are strongly influenced by actual tillage depth, while disc seeders are often operated at shallower depth than tine systems.

**Fig. 4: Undercut disc openers offer superior penetration ability in hard ground with greater associated soil disturbance (eg. Flexi-Coil *Barton* – top- and Austil *MT2500* – bottom - dual banding designs shown)**

## RESIDUE CUTTING WITH DISCS

A peripheral disc speed (Fig. 5) greater than the forward speed is required to induce a positive sliding cut action at the disc edge and improve residue cutting. This situation normally occurs with most coulter designs.

At a zero working depth, the coulter disc behaves similarly to a towed rigid wheel rolling on a firm surface. As the working depth increases, the peripheral speed of the disc in rotation gradually increases beyond the value of forward speed due to the soil frictional forces driving the disc at an equivalent radius smaller than the outer disc radius. This effect assists in the process of cutting through stubble, by creating a sliding cut additional to the parting or wedging effect under the pressure of a sharp cutting edge.

Generally speaking, residue cutting forces are best minimised by combining an effective sliding cut action with an efficient wedging component. These conditions are obtained when i) there is enough soil reaction to sustain efficient compression and wedging effects by a sharp cutting edge at the soil surface (eg. sufficient soil strength) and, ii) there is adequate differential speed at the cutting edge to achieve efficient slicing (eg. higher rotational to forward speed ratio, promoted by thicker discs and smaller wedge angles).

Coulter features such as ripples and bubbles (eg. Fig. 2) promote a more effective driving effect, which ensures differential speeding up of the outer cutting edge and minimises risks of blockage. V paired discs are often staggered or of different diameters in an effort to create different peripheral speeds at the cutting front, promoting an improved cutting effect.

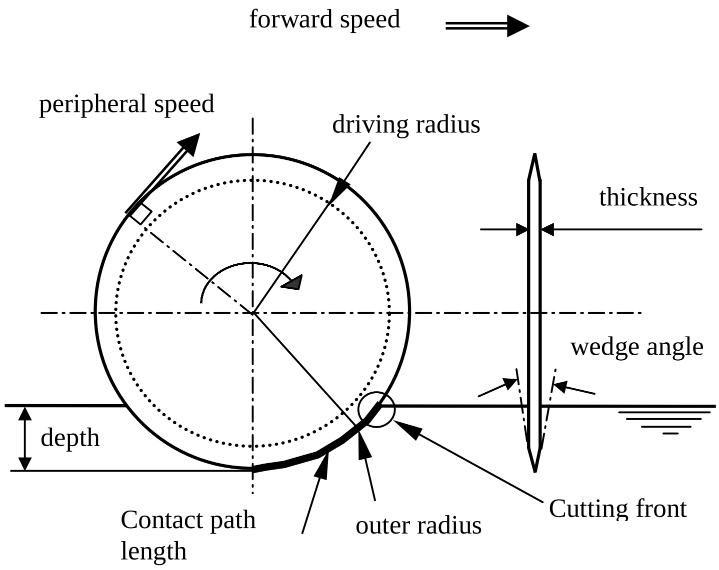


**Fig. 5: Basic disc coulter geometry**

The depth setting of a coulter is equally critical to minimise either stubble hair-pinning problems (ie. depth being too shallow) or forward pushing actions hindering cutting and leading to choking (ie. coulter setting too deep) - see Fig. 6. A given disc diameter is normally associated with an optimum working depth for best cutting in a given soil condition.

Angled and undercut discs rely on soil reaction forces applied to either, or both, the active and passive sides of the disc for effective rotation. In soft, gutless soil conditions, there may be too little soil reaction to adequately drive the disc and handle residue properly (NB: the problem may be exacerbated by tight bearings and other braking devices – scrapers, cleaner wheel etc…). A slower than travel peripheral speed results in a less effective sliding cut action as it is combined with an increased forward push effect.

Scalloped/notched discs can more easily achieve deeper depth from their superior penetration ability (ie. reduced path length of contact area) and minimise the residue pushing tendencies by trapping residues within the notches emphasising the parting component of cutting. These coulters can therefore work deeper while choking less readily, but may achieve reduced cutting ability by minimising efficient sliding cut actions.

Holding and pressing the stubble to the ground on either side of the coulter cutting front (eg. using trapping skids or pincher wheels) are means to further improve the cutting ability of coulters, especially through thick mats over softer soil condition. These devices (eg. Fig. 7) place some or all of the residues under tension when cutting and rely on optimum pressure constantly applied by the trapping wheels/skids. Their performance may be affected by the lack, or excess, of down pressure in hard and soft soil conditions, respectively. Drum fitted coulters are less likely to benefit in this manner due to the location of the drum relative to the cutting front.

power. Soil compaction may occur as a result of heavy disc load distribution across the soil/disc contact area along its forward cutting edge (Fig. 5). Maximum compaction risks could occur in prone soils (eg. compactable clayey soils) using V paired discs (least efficient due to their negative tilt) alone without deep working coulters.

Increased penetration can be achieved by:

- Reducing the contact area (eg. using thinner discs, smaller disc diameter or notched edge designs to concentrate loading)
- Using positively tilted discs (ie. undercut designs) which present an improved angle of approach, rather than negatively tilted (eg. V paired discs) or vertical discs.

## SOIL DISTURBANCE ASPECTS

The lateral soil throw generated by discs is function of soil conditions, operation settings and design features. With angled and undercut discs, their usual association with cleaner wheels is designed to control soil throw, by stopping soil from being entrained by the disc. The effectiveness of a cleaner wheel, as a soil throw controller, can vary with the depth of cut, speed of

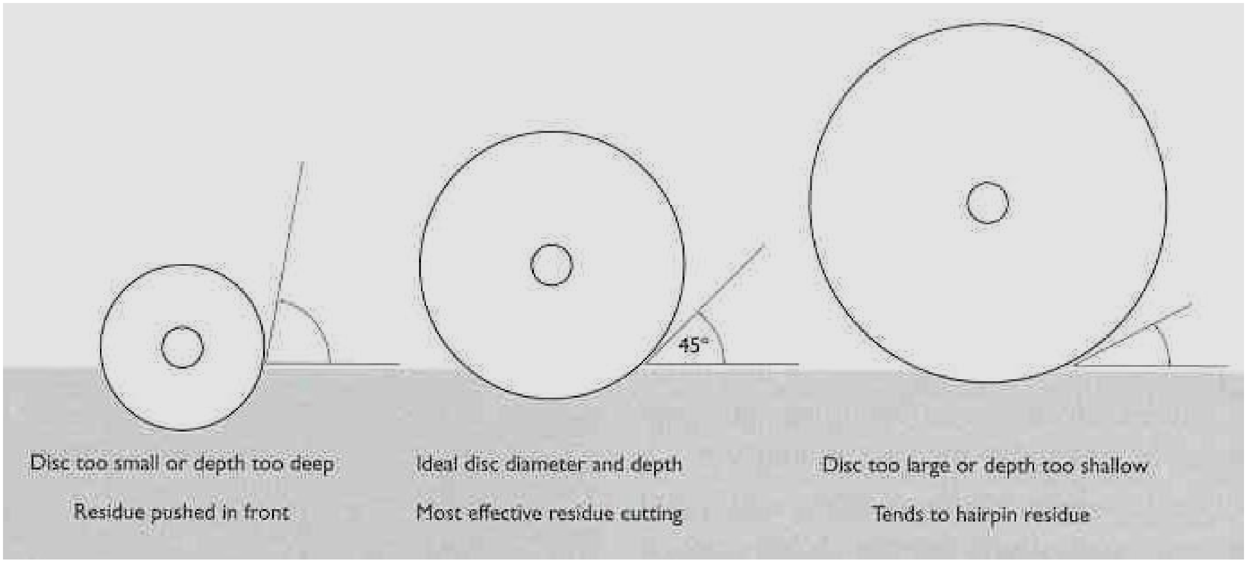


**Fig. 6: There is an optimum working depth for residue cutting with any given disc diameter**

## PENETRATION ABILITY

Ground penetration with discs can be a major issue as penetration ability in a given soil environment is dictated by available machine weight and disc geometry. Implement weight distribution front to back, and centre portion to wings must be designed to allow all units to penetrate equally. The heavier the machine, the better the penetrating ability, however at a potentially great cost of soil compaction and tractor

operation and position relative to the disc (ie. splashing due to soil hitting the cleaner wheel tends to increase when operating at deeper depth, higher speed and with wheel positions pushed back to additionally operate as a furrow closer). Some controlled amount of soil splashing can successfully incorporate herbicides such as *trifluralin*, except over the usual 'dead' inter-row in the centre part of the machine. Uncontrolled soil splashing, however, can lead to significant furrow ridging effects, similarly to tine seeders.

**Fig. 7: Pincher wheels can help cutting through residue provided enough extra pressure is available beyond that required for disc penetration, without inducing wheel sinkage in soft soils (eg. Morris *Never Pin* design shown)**

**Fig. 8: Disc edge bevel position influences smearing risks with angled coulters (eg. *Morris* fertiliser opener design shown)**

**Fig. 9: NSW disc seeder development featuring paired undercut discs working in opposition and spaced apart to loosen a narrow band of soil. At speed, a soil wave is formed under which seeds are delivered followed by a wheel squashing action achieving furrow closure. Principles of the paired disc loosening process were investigated in the UK in the mid 1980s which demonstrated higher energy efficiency under optimum settings (eg. *Wyalong Rene* speed drill design shown)**

With coulter discs operating in sticky and compacted soils, lateral soil throw can also be substantial, where adhesion to the sides of the discs can allow excessive soil to be flicked out of the furrow unless side skid options can be fitted.

Coulter discs design features (eg. flat, bubble, ripple or wavy) allow some varying degree of furrow disturbance to provide a desired furrow seed bed effect for the following seeding unit and promote superior soil/seed contact and root system development. However, the higher disturbance typically implies lower penetration ability. To further increase the amount of soil tilth, the concept of *Zone Tillage* relying on staggered dual or triple wavy coulters, creates a narrow band of tilled soil ahead of a seeding unit.

## SMEARING

Smearing is the formation of thin compacted layers, which harden upon drying. These layers can represent a significant hindrance or even total barrier to root development depending on severity. The formation of smeared layers is promoted under high stress situations (eg. at the share cutting edge or bevel area of a disc) under wet soil conditions with some amount of clay content.

**Fig. 10: Double shoot single coulter disc seeder with press wheels used as gauge-wheels for contour following (*Cross-Slot Opener BioBlade* design shown)**

With angled and undercut disc designs in particular, the side bevel edge can promote variable smearing conditions depending upon its orientation. When facing the undisturbed part of the furrow (ie on the passive side of the disc), the bevel compacts soil against the undisturbed zone under higher stresses and smearing can easily develop in wet conditions (NB: the thicker the disc, the greater the strain imposed on the soil and the greater the extent of smearing damage - this situation however promotes self sharpening of the disc. When the bevel is placed on the active disc side (eg. cleaner wheel side), the compacting effort of the bevel edge is minimised by lower stresses against the loosened soil and poses a lesser smearing risks. Under the effects of soil tool adhesion, regular cracks typically open along the smeared surfaces, which may minimise penalties.

The option of coulter-tine combinations can offer some of the residue cutting benefits of disc openers while generating more soil tilth, to achieve, for instance, wider seed spread on the sowing row. In the path following a disc coulter, the soil flow around the following share is typically altered and the draft force of the combination may be lower than with the share alone, subject to optimum design and setting of the coulter disc.

## DISCS AND STICKY SOILS

Operating when conditions are too sticky can result in uncontrolled soil build up and poor performance of disc systems. Delaying the sowing operation until the top soil layer has sufficiently dried, together with minimising the operating depth, can significantly improve disc system performance and, under these conditions only, higher speeds (eg. 12-15kph) were found to improve self cleaning ability and maintain stable soil build-ups.

Early evaluation results suggest that single discs (vertical or undercut designs) are potentially best able to handle sticky conditions, provided they work shallowest and successful disc scrapers are combined with a side wheel designed to operate as an effective cleaner wheel. V paired disc designs were found to be more prone to uncontrolled soil build-ups by exerting greater compaction efforts onto the furrow walls. Further work is underway (SAGIT Project WAB 1/03)

## OPPORTUNITIES WITH DISC SEEDERS

Modern disc opener technology offers a wide range of capabilities to cater for many soil conditions, and can provide an effective basis for low soil disturbance direct seeding, with opportunities for high work outputs. Specific disc seeder configurations aiming to increase seed bed utilisation may additionally assist with optimising crop yield performance without the weed seed stimulation associated with high soil disturbance tillage.

A key feature of disc implements remains that disc penetration is dependent upon available down pressure. The down pressure requirements greatly vary across a range of soil conditions (eg. within paddocks). The ability to tailer disc unit pressure to exact ground condition on the go (eg. hydraulic system) allows the gauge wheel loading to be continuously optimised, avoiding the disc riding out of furrow in hard patches or the depth wheel sinking/bulldozing in soft patches. This feature is particular useful for achieving accurate seed placement with dual banding boot systems on single discs. A commercial solution (Fig. 10) now provides an automated feature of constant down pressure on press wheels (also acting as depth wheels) regardless of soil conditions.

**<u>Further information</u>:**

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