Forces on Double Disc Coulters with Different Angles of Attack for a Planter Unit

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Abstract

It is long known that reactions resulting from the penetration of coulters into the compacted soil generate more strain on the crop row, decrease the service life of its components, and represent an unwanted maintenance cost, often at mid-seeding. The objective of the study was to assess straining on a double disc coulter of a commercial planter using a dynamometric car, which measured the vertical and horizontal forces operating on the three double disc supports at different angles of attack. Forward speed ranged in three levels and working depth ranged in two levels. The tests were performed in the Stara experimental farming area in the city of Não-Me-Toque, RS, Brazil. It was possible to conclude that the range of angles of attack of offset double discs decreased the power requirements on the crop rows. It was also concluded that the working speed had a significant effect only on the vertical force component, due to the lager angular opening.

Keywords

I. LITERATURE REVIEW

The force required to pull agriculture equipment has been studied constantly in several research institutions and by many agricultural machinery manufacturers. The progressive increase in the number of crop rows in both continuous-flow and precision planters caused force requirements to be assessed with more emphasis.

According to Portella [1], special attention should be given to planter coulters, especially because of the difficulties imposed by this farming technique. One of these difficulties is soil disruption in the seeding row, which is aggravated by the increasing growth of crop residue on the surface. These crop residues were about three tons per hectare (dry matter) when the no-till system first started in Brazil in the 70s; currently they exceed 10 tons per hectare depending on the crop rotation system applied.

The development of no-till planters in Brazil was based on the improvement of coulters. Each machine model presents its own constructive features, versions, and options of coulter mechanisms. The systems most often applied are the offset double disc system for the seeding of winter crops with reduced spacing between seeding rows (under 200 mm) and the multiple system (coulter disc, knife, and double disc) for the seeding of summer crops with larger spacing between rows (over 300 mm).

Three factors support the soil disruption efficiency of a no-till planter: straw cutting, straw flow, and the opening of seed and fertilizer furrows. Thus, for satisfactory performance of soil disruption the geometry of coulters should be considered, as well as their arrangement and line-up under the planter.

The double disc coulter presented in Figure 1 comprises two flat discs of different diameters, with either matching centers
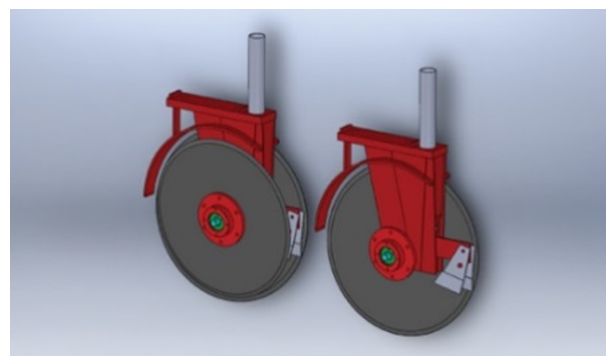

Fig. 1: Double Disc Coulters. Source: Fankhauser 5046 Catalog.

or not. Considering its adjustment, the disc cuts the straw and opens a furrow on the ground for seed and/or fertilizer placement.

According to Mion et al. [2], the double disc has advantages when facing shear stress in comparison with the single-disc coulter, because it is arranged with one disc at each side, guaranteeing more stability and support. Because of this constructive arrangement and a larger soil friction area, the double disc requires more vertical force to cut the straw and disrupt the soil. A strong influential factor in the no-till system is the active forces on coulters, which play an important role in the performance of planter units. Most often, the forces working on these coulters are directly associated with soil cover, sowing speed, type of soil, and soil moisture content.

Studies performed by Machado et al. [3] indicate that the power required to pull a no-till planter is lower than that recommended by agricultural machinery manufacturers on their brochures. Authors say this divergence is caused by the development of areas with several types of soils cultivated with no-tillage. Hence, these areas present well above the required values, presenting no issues concerning the recommendation of traction force.

Seeding operations of the main commercial crops (wheat, soybean, corn, and sorghum) are within the depth limit

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Fig. 2: Dynamometric car and test unit.

Fig. 3: Data acquisition module MGC Plus.

between 2 cm and 7 cm. Thus, the soil resistance to the penetration and movement of coulters in this depth limit is influenced especially by clay content, degree of compaction, and moisture content of the soil.

Working speed also plays an important role in no-tillage operations, for both the efficient crop delivery and the distribution of resulting strains in the tractor-planter set.

Trintin et al. [4] proved through tests that increasing speed enhances the operational capacity of the set, and therefore, increases fuel consumption and the requirement of mean power in the drawbar.

Milagres et al. [5] found that a planter adjusted with double disc coulters did not present significant influence on the traction force required when the speed changed from 3.7 km/h to 7.6 km/h.

It is known that agricultural machinery manufacturers want to offer larger products with lower power requirements. This study contributed to evaluate the impact of changing the angles of attack of double discs on the vertical and horizontal forces of the crop rows of a planter.

II. MATERIALS AND METHODS

The tests performed in this study were develop in the Stara experimental farming area owned by Stara Indústria de Máquinas Agrícolas, in the city of Não-Me-Toque, RS, Brazil, in August 2014.

A dynamometric car specifically developed for this research measured vertical and horizontal forces, and momentum operating on three double disc supports with different angles of attack. Forward speed ranged in three levels, and working depth ranged in two levels.

In order to obtain the active forces identified by this study a dynamometric car, made by the Engineering Department of Stara, was used. This car includes a drawbar attached to the tractor and a drive wheel set powered by a pair of hydraulic drives, which are positioned at the exact working height by tractor command (Figure 2).

The lower part of the car presents a test unit comprised by the set of crop rows where the double disc supports were attached, at their respective angle variations. The system used for data collection and acquisition was the MGC Plus by HBM, fed by a direct current unit. The software that read and converted the signals collected for pre- and post-processing was the Catman Easy also by HBM, both secured in the board

of the dynamometric car (Figure 3). The study included double discs in the offset disc adjustment, which is currently the most commonly used coulter for winter crops. Each support had a different angle of attack (34°, 36°, and 38°).

The cutting pressure of each support ranged between 210 kgf and 294 kgf and it was adjusted in the helical spring pressure system of the crop row. For each cutting pressure variation, there were two depths (3.5 cm and 5.0 cm) and three speeds (4 km/h, 8 km/h, and 12 km/h).

Depth was adjusted through the depth gauge set attached to the double disc support. Both cutting depth and speed applied in this study resulted from the operational capacity of the planter unit and tractor set currently sold.

This test was performed in a field area with spontaneous ryegrass soil cover, with total length of 150 m, divided into three plots of 50 m.

A. Statistical Analysis

The means were compared by ANOVA with factorial experimental design $3 \times 3 \times 2 \times 2$, at 0.05 significance level. The free software SISVAR, from the Federal University of Lavras, MG, Brazil, was used.

The statistical analysis was developed to assess the interaction between the main variation treatments for the angle of attack of the double disc support (34°, 36°, and 38°) and the secondary speed treatments (4.0 km/h, 8.0 km/h, and 12.0 km/h), and between the pressure variation of the regulating spring of the row (210 kgf with pressure (WP) and 293 kgf without pressure (WOP)) and disc depth (3.5 cm and 5.0 cm).

III. RESULTS

Data collected included horizontal forces, which were responsible for the traction component of the crop row; and vertical forces, which were responsible for pressure components on the crop row to achieve the working depth.

The data analysis of Table I and II verifies that only the tested angles and working depth (position) presented statistically significant differences. Among the angles, 34° presented the lowest force requirement, and working depth of 35 mm required about 30% less horizontal force. The forward speed did not present significant differences, that is, pulling the

TABLE I: Analysis of Variance of the Horizontal Force

FV	GL	SQ	QM	Fc	Pr > Fc
Angle	2	681.033889	340.516944	11.894	0.0014
Speed	2	81.623889	40.811944	1.425	0.2783
Position	3	3482.335556	1160.778519	40.544	0.0000
Angle*Speed	4	32.549444	8.137361	0.284	0.8826
Angle*Position	6	299.672778	49.945463	1.744	0.1939
Speed*Position	6	137.042778	22.840463	0.798	0.5896
error	12	343.563889	28.630324		
Corrected total	35	5057.822222			
CV (%) =	6.74				
General mean:	79.4222222	Number of observations:		36	

TABLE II: Analysis of Variance of the Vertical Force

FV	GL	SQ	QM	Fc	Pr > Fc
Angle	2	125.362222	62.681111	6.397	0.0129
Speed	2	435.290556	217.645278	22.211	0.0001
Position	3	7700.485278	2566.828426	261.945	0.0000
Angle*Speed	4	148.772778	37.193194	3.796	0.0322
Angle*Position	6	175.168889	29.194815	2.979	0.0508
Speed*Position	6	99.213889	16.535648	1.687	0.2073
error	12	117.589444	9.799120		
Corrected total	35	8801.883056			
CV (%) =	2.23				
General mean:	140.5861111	Number of observations:		36	

planter between 4 km/h and 12 km/h does not change the traction requirement for these double discs tested, because the variation of the angle of attack operates only on the vertical force.

However, when analyzing vertical force, statistical differences were observed in all components with considerable significance for working depth, as expected. Greater depths required greater vertical forces. The lowest working speed also demanded less vertical force, which confirms several studies that affirm that increasing speed results in smaller seeding depths. Thus, increasing the force on the double disc (pressure) is required in order to maintain depth.

The difference found in the vertical force may be explained partly by the constructive arrangement of the double disc, agreeing with Mion and Benez [2], who affirm that the double disc set requires more vertical force to cut the straw and disrupt the soil, considering that in the constructive form its arrangement has a larger soil friction area.

The present research also confirms this variation, but the main reason for the increased traction was the additional pressure on the double disc set.

IV. CONCLUSIONS

It was possible to conclude that the range of angles of attack of offset double discs decreased the power requirements on the crop rows. It was also concluded that the working speed had

a significant effect only on the vertical force component, due to the lager angular opening.

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