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EFFECT OF SOIL FORCES ON THE SURFACE OF MOLDBOARD PLOW UNDER DIFFERENT WORKING CONDITIONS

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Abstract

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The study was conducted to investigate the effect of forces on the surface of moldboard plow (model: 1LE – 435) at three angles (65°, 75°, 90°), three depths (15cm, 20cm and 25 cm) and three moisture contents (21%, 24% and 27%) and variable on soil bin, while the forward speed of plow was kept constant (2 km/hr). In total 11 sensors were fixed on the surface of different parts of plow to measure draft forces applied on the surface of plow. Results revealed that the maximum force was observed at 90° angle, which decreased with the decreasing angles. It was also observed that varying angles have considerable effect on the width of cut. The maximum soil forces were exerted on the share of plow at all angles, while minimum force was observed on the curvature of plow. The effect of different moisture content, working depths and rake angle were significant ($P<0.01$). It was also observed that moisture content has inverse relation with soil forces while depth has direct relation with soil forces.

Key words: Soil force sensors, soil and tool parameters, surface of moldboard plow, paddy soil, soil bin

Introduction

Tillage is a process of creating soil conditions for seed germination and growth of crop (Al-Suhaibani and Ghaly, 2010). The tillage of soil is considered one of the biggest farm operations as the tillage operation requires the most energy on the farm. Moldboard plow is widely used by farmers as a primary tillage tool. Its performance evaluation is essential in order to reduce the cost of tillage operation (Manuwa and Ademosun, 2007; Gopal Shinde et al., 2011).

The draft forces on tillage tools based on current soil and operating conditions of tillage tool are important parameters for design and manufacturing tillage implements (Saunders et al., 2000). These include soil type and condition, moisture content and plowing depth etc. (KarimiInchebron et al., 2012). In clay soils, implements have higher draft forces as compared to the loam and sandy soils. In special range of moisture content, implements have lowest draft and out of this range, they may have higher draft. Tillage depth, working width, geometry and stability arrangement of implements and forward speed are parameters that may have affect on draft Naderloo et al. (2009).

The specific draft (force per cross sectional area of worked soil) for moldboard plow, chisel plow and disc harrow at different soil conditions were investigated by Arvidsson et al. (2004). They found that the specific force was generally the highest for the chisel plow and the lowest for the moldboard plow and the disc harrow. Most of the studies on draft forces involve different formulas and equations to measure draft forces. These studies however provide data on soil forces, but these are time consuming and laborious. Thus, the use of sensors can provide quick results and can be used to find out forces in three dimensions. Godwin, (1975) used transducer (sensors) to measure the horizontal force, the vertical force and the resulting moment of the total moldboard assembly. Sensing equipments are used to measure the soil strength and soil deformation under the application of various the types of tool working conditions (Chung et al., 2008). Measuring the draft requirements of tillage tools is accomplished by the sensors, which have been extensively studied by many research-

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ers (Godwin 1975; Zoerb 1983; Godwin et al., 1993; Kirisci et al., 1993; Chen et al., 2007). Little work has been conducted to measure the soil forces on the different part of moldboard plow with sensors, which is important for the designers and manufactures.

The mains purpose of this study is to measure the soil force on tillage mould board with following objectives. (i) To measure the soil force on the surface of the moldboard plow. (ii) To measure the soil force at different angles in different soil moisture content.

Materials and Methods

The study was conducted at Soil Mechanics Laboratory, Department of Agricultural Mechanization Engineering, College of Engineering, Nanjing Agricultural University China.

Experiments were conducted on soil bin (6 m x 2.5 m x 0.8 m) by using moldboard plow (model 1LE - 435) with varying moisture contents (21%, 24% and 27%), depths (15cm, 20cm and 25 cm) and angles (65°, 75°, 90°) shown in Figure 1a,b and the schematic diagram and top view of actual experimental condition of soil bin. The speed of the plow was kept constant 0.55m/s.

Soil Bin

Soil bin consists of paddy soil (silty clay), carriage, electronic motor (7.5 kW), speedometer, chains and move able farm. The carriage moves on rails using two chains fixed on the frame. The movement of carriage was made possible with control speedometer.

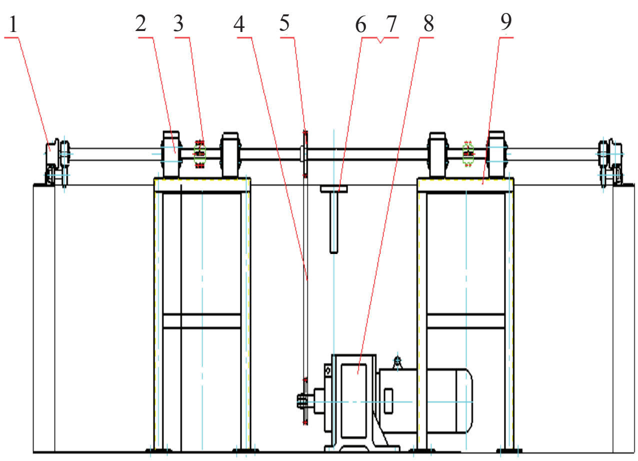

Fig. 1a. Diagram of soil bin

(1 Bearing shaft Stand, 2 Block, 3 Sprocket-driven Chain, 4 Main driven chain sprocket, 5 Driven plough, 6, 7 - Frame connections, plough, 8 motor, 9 Frequency stent.)

Ploughing depths and angles were controlled by adjusting the position of the rectangle tool rod (75 cm long) on the frame and fixed with the frame through that rod we can also change the angle of moldboard plow.

Soil Physical and mechanical Properties

The soil physical and mechanical properties such as soil texture, and bulk density, soil cohesion, soil internal friction angle, were measured before and after each experiment, while soil cohesion and internal friction angle were measured using direct shear test apparatus. The soil texture was clay (47% clay, 42% silt and 11% sand). These are summarized in Tables 1 and 2.

Soil forces on the surface of Moldboard Plow

Study the soil forces, which act upon a moldboard plow when working at different settings, should assist in enabling the correct configuration of width, depth, speed and field condition be selected to optimize productivity.

Eleven holes (2.52cm each) were made on different parts of moldboard plow and cylinders with threads were fixed on the backside of plow for the installation of sensors (5 cm

Table 1
Measurement of soil cohesion and soil friction angle before and after tillage at different soil moisture content

Soil moisture content (%)	Soil cohesion (C)	Friction angle (Φ)
	Before tillage	Before tillage
21	6.96	40
24	5.49	39
27	4.29	28

Fig. 1b. Overview of soil bin

height and 5 cm width). There were 11th sensor's was fixed on the surface of the moldboard plow to measure the soil force which is shown in (Figure 2), first 3 sensors were installed on shear part, while the sensor 4 to 6 were installed on shear moldboard joint part which we call curvature and sensors from 7 to 11 were installed on the moldboard part of plow. The data of these sensors (voltage) were collected into excel sheets as output file on computer loaded with Labview software which was derived with help of PCI-1710 HG card on computer shown in Figure 3.

Statistical analysis

This research was planned as RCBD with three replications. Soil forces of moldboard plow in different working conditions, soil moisture content, rake angles and depths were analyzed by SPSS (ver. 16, SPSS, Inc., Chicago, IL, USA) with ANOVA.

Results and Discussion

Soil forces on the surface of moldboard plow at 21% moisture content and tool parameters

Soil forces on the surface of moldboard plow at 21% moisture content, different depths of operation and angles are shown in Figure 4. It indicates that at the depth of 15cm, soil forces were 78.39, 93.42 and 88.14 on share, 31.27, 36.28 and 37.08 on curvature and 58.28, 59.2 and 58.32 on the moldboard parts of moldboard plow at 65^0, 75^0 and 90^0 angles respectively. It is observed that minimum forces were applied on curvature at 65^0 angles, while maximum forces were applied on share part of moldboard plow at 90^0 angles. Similar trend was observed at 20 cm and 25 cm operating depths respectively.

Soil forces on the surface of moldboard plow at 24% moisture content and tool parameters

Soil forces on the surface of moldboard plow at 24% moisture content, different depths of operation and angles are shown in Figure 5. It indicates that at the depth of 15cm, soil forces were 51.97,76.2 and71.08 on share, 39.11, 41.73 and 31.93 on curvature 52.73, 44.42 and 62.27 on the moldboard parts of moldboard plow at 65^0, 75^0 and 90^0 angles respectively. It is observed that minimum forces were applied on curvature at 65^0 angles, while maximum forces were applied on share part of moldboard plow at 90^0 angles; similar trend was observed at 20 cm and 25 cm operating depths respectively.

Table 2
Main soil strength parameters as affected by the actual soil bulk density and soil moisture content

Normal Stress (kPa)	Bulk density g/cm^3 Before tillage			Bulk density g/cm3 After tillage		
	1.07	1.22	1.38	1.27	1.34	1.45
200	22.114	16.345	6.153	19.383	14.614	6.922
300	23.268	17.326	10.576	21.153	15.768	9.038
400	22.922	19.614	11.153	22.806	18.845	10.384

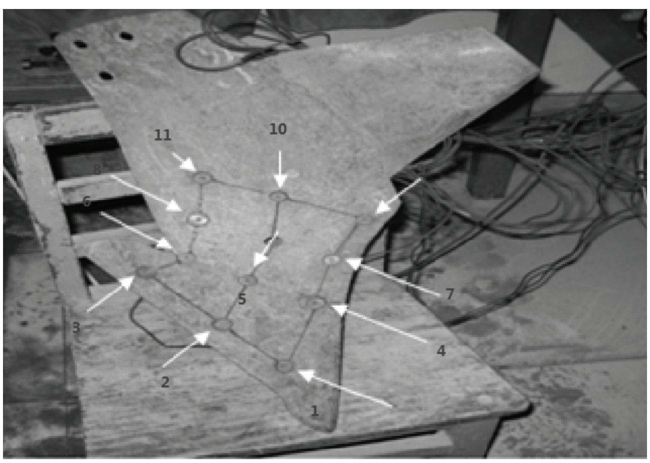

Fig. 2. Front view of moldboard plough with eleven sensors

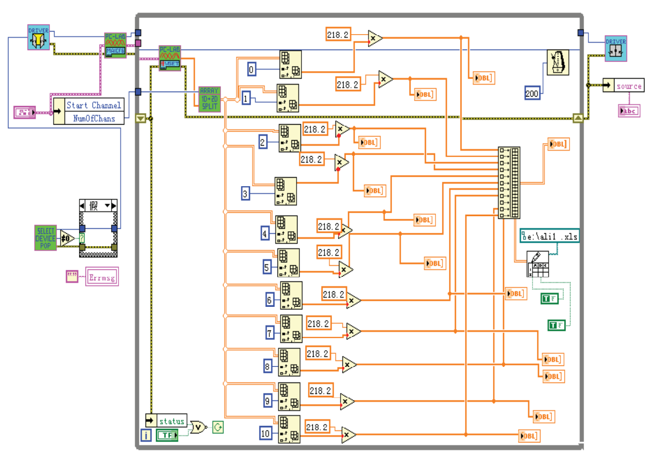

Fig. 3. Program of LabVIEW for data collecting

Soil forces on the surface of moldboard plow at 27% moisture content and tool parameters

Soil forces on the surface of moldboard plow at 27% moisture content, different depths of operation and angles are shown in Figure 6. It indicates that at the depth of 15cm, soil forces were 35.53, 70.94 and 56.62 on share, 55.8, 76.4 and 53.65 on curvature and 23.02, 37.71 and 53.78 and 58.32 on the moldboard parts of moldboard plow at 65^0, 75^0 and 90^0 angles respectively. It is observed that maximum forces were applied on curvature at 65^0 and 75^0angle followed by share and moldboard, while at 90^0 angle forces on curvature and moldboard almost same but maximum forces were applied on share part of moldboard plow. It was also observed that minimum forces were applied on moldboard and maximum forces applied on share part of moldboard plow part. It statistical analyses of data were highly significant ($P < 0.01$).

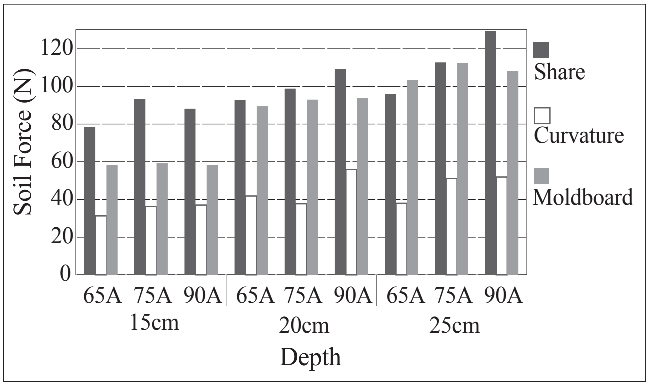

Fig. 4. soil forces at 21% moisture content and tool parameters with different angles

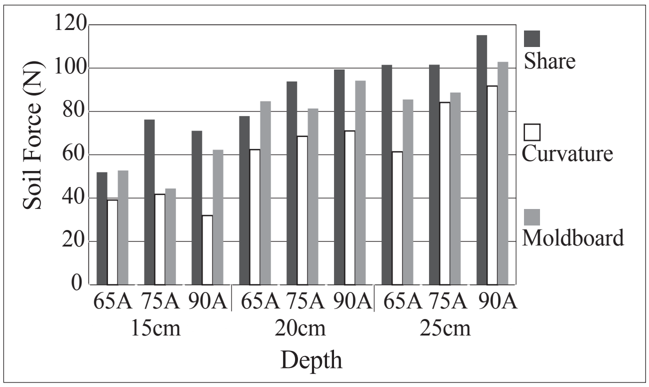

Fig. 5. Soil forces at 24% moisture content and tool parameters with different angles

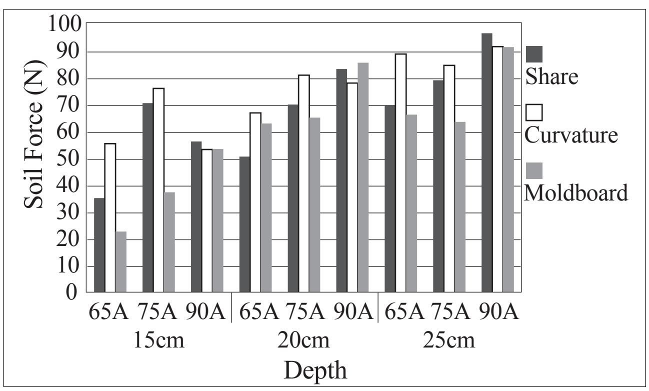

Fig. 6. Soil forces at 27% moisture content and tool parameters with different angles

The above results verify the findings of Yousef Abbaspour et al. (2006) as concluded that an increase in soil moisture content resulted in a decrease in draft forces. Taniguchi et al. (1999), Naderloo et al. (2009) and Olatunji et al. (2009) observed that draft required for a given implement are affected by the soil conditions and tool parameters. In addition, Marakoglu and Carman (2008) concluded that draft forces increase with the increase in rake angles

Conclusions

Soil forces on the surface of moldboard plow at 21% moisture content and tool parameters showed that minimum forces were applied on curvature at 65^0 angle, while maximum forces were applied on share part of moldboard plow at 90^0 angle, similar trend was observed at 20 cm and 25 cm operating depths respectively.

It is observed that maximum forces were applied on curvature at 65^0 and 75^0angle followed by share and moldboard, while at 90^0 angle forces on curvature and moldboard almost same but maximum forces were applied on share part of moldboard plow. It was also observed that minimum forces were applied on moldboard and maximum forces applied on share part of moldboard plow part.

It was clear from the study that maximum force measured in 21% of moisture content at 90^0 angles of moldboard plow parts.

It has shown that ploughing should be carried out with low angle 65^0 and depths (15cm)

Acknowledgments

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