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Effect of Coating Chisel Plow Shares with Some Materials on Draft Force Requirement

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ABSTRACT

This study was devoted to verifying the effect of using three different coating materials on the draft requirement of chisel plow shares. Four types of chisel plow shares with the same geometric dimensions of (70 mm width, 0.26 rad as lift angle and 45° for cutting angel) were used. One chisel plow share was kept without coating with its standard iron as a control, the other three chisel plow shares were coated with copper, aluminum and stainless steel. Experiments were conducted using an open air soilbin with a digital electronic dynamometer attached to Kobota tractor of 26 KW to measure the required draft of each chisel plow share in term of the horizontal force values. Measurements of the required draft for all chisel plow shares were assessed at three different depths 15, 20 and 25 cm, and three different forward speeds of 0.58, 0.75 and 1 m/s (2.1, 2.7 and 3.6 km/h) with three replications using a completely randomized design in silty clay loam soil. The results revealed that the stainless steel-coated share has the lowest horizontal force in all depths and almost at all forward speeds. Therefore, it is recommended to coat shares with stainless steel due to its low price due to the low price of stainless steel locally and internationally and because of the lower horizontal force required to use it with maintain low levels of shares corrosion.

Keywords: tillage tools, coating materials, shares protection, draft force

INTRODUCTION

Soil tillage is a crucial phase of agricultural production that involves the mechanical work of tillage instruments to change the soil structure; this activity needs a lot of energy to break down, invert soil layers, reduce clod size and rearrange aggregates, and wears out tillage tools a lot (Ademosun, 2014). During service, shares, as sections of ploughs, are subjected to wear, the abrasive impact of the soil particles, which is dependent on the soil moisture and composition, wears out those parts (Kim et al., 2021). The plowing process is affected by the forward speeds and the depth of the plowing (Brune et al., 2018). The design of the tillage tool is considered the most important factor in the plowing process because it is the connecting element that is related to different soil types (Mak et al., 2012). Now more than ever, efficient management is the major key to success in the farming business so, the study of soil reaction on tillage tool is the primary goal of all design engineers by predicting the effects of plowing and controlling it as much as possible. At present, many studies are developing the tillage tool to obtain the least strength to react soil (Ranjbarian et al., 2017). The development of tillage tools would be highly beneficial as this would reduce the cost of seedbed preparation. Because this development in the plowing tool seeks to reduce the forces of soil reaction to the plowing tool, which leads to reduce the required fuel and thus reduce the total cost of plowing (Salar, et al. 2017). Plough shares' protection methods from wear have essential assumptions that higher material hardness increase abrasion wear resistance, but influence of the used coating material properties on wear is vary and may depends on many other operational factors and conditions. To achieving optimal solution of abrasion wear protection methods have to analysis the tribosystem experiments in context with the laboratory and exploitation investigations (Ivusic and Jakovljevic, 1992). Many protection techniques have been discovered and used over the years to increase the abrasive wear resistance of tillage tools. Harding the tillage tools' shares used to be a common way to improve surface properties of tillage tools where an alloy is homogeneously deposited onto the shares' surface of a basic material by different techniques of welding, with the purpose of increasing hardness and wear resistance (Buchely et al., 2005; Mihaljevic, 1993). A wide variety of hard facing alloys is commercially available for protection against wear, so the right material selection is the key point and it is essential for protection process. Selection of the material should be considered on the basis of its wear resistance, hardness characteristics and properties (Bhakat et al., 2004). El-Sheikha and Hegazy (2021) cleared that the differences in price for treated and untreated shares in not high and worth saving shares for longer working life than changing them frequently after wearing. Also, lower drawbar pull forces proved the advantages of using coated shares as low drawbar pull which is an indicator for lower fuel consumption and lower operational cost. So, in the current research work, three different coating materials were tested to study their effect on the chisel shares required draft force.

MATERIALS AND METHODS

Field experiments were conducted at a private farm of 500 m² area (about 1/8 fed.) in Fraskor, Damietta governorate, in summer of 2021. Soil texture was silty clay loam with 12%

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sand, 55% silt and 33% clay and soil moisture content was about 21%.

All measurements were made at three forward speeds of 0.58, 0.75 and 1 m/s given from a KOBOTA tractor of 26 KW. At lift angle of 0.25 rad at three different depths of 15, 20 and 25 cm using 4 chisel plow shares that have the same geometric dimensions: 70 mm width, and 45° cutting angle. The first share was left as it is without coating to be standard (control) as shown in Fig. 1a, the second share was coated with copper as shown in Fig. 1b, with a thickness of 2 mm, the third share was coated with aluminum metal as shown in Fig. 1c, with a thickness of 2 mm and the last share was coated with 2 mm thick stainless-steel layer as shown in Fig. 1d.

An open air soilbin manufactured by (El-Sheikha 2008) was used to simulate the field condition for testing the different coated chisel plow shares. A digital electronic dynamometer is installed to read the horizontal force values, and it is connected to the other side of the winch as shown in Fig. 2. the winch is used to transmit the rotational motion from the PTO to the test carriage by connecting a flexible connection between the tractor and the winch as shown in Fig. 3.

Fig. 1. Four type of chisel plow shares
(a: iron, b: copper, c: aluminum and d: stainless steel)

Fig. 2. Open air soilbin with a digital electronic dynamometer

Fig. 3. Connection between tractor and the winch by flexible coupling

RESULTS AND DISCUSSION

Table 1 shows the effect of forward speeds of the test carriage under different tillage depth, lift angle of 0.26 rad, on the draft force of tested used tillage tools (chisel plow shares) (Iron share without coating , Copper plated chisel plow share , Aluminum plated chisel plow share and Stainless steel - plated plow share).

Table 1 . Observed soil reactions (draft) affected by forward speeds for the tested tillage tools (chisel plow shares) under different tillage depths with lift angles of 0.26 rad.

Depth, cm	Coating material (Metal)	Soil reaction (draft force, kN)		
		Forward speeds, m/s		
		0.58	0.75	1
15	Steel (iron)	0.92	1.30	1.40
	Copper	1.00	1.34	1.76
	Aluminum	1.17	1.34	1.39
	Stainless steel	0.76	0.97	1.23
20	Steel (iron)	1.99	2.26	2.67
	Copper	2.04	2.41	2.82
	Aluminum	1.76	2.16	2.35
	Stainless steel	1.38	1.79	2.36
25	Steel (iron)	2.67	2.80	2.99
	Copper	2.56	2.75	2.95
	Aluminum	2.68	2.84	2.9
	Stainless steel	2.24	2.39	2.77

Effect of tillage depth and forward speeds

It is clear from the Figures 4, 5, 6 and 7 that by increasing forward speed the draft force increases at all depths, because of the increase in the stress on the share, so the reaction of the soil becomes higher. Also, when the depth was increased in all experiments at different speeds, the draft force also increased, due to the increase in the area of the share, which causes friction with the soil, and also due to the increase in the number of layers of soil as we go down, and also due to the increase in moisture, the greater the depth in the soil, the higher layers are more lightness and higher porosity due to less pressure on it and also less moisture.

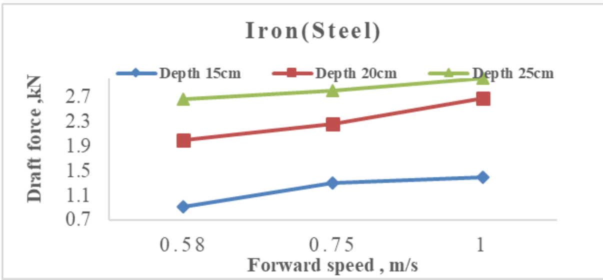

Fig. 4. Draft force vs. forward speed for iron chisel plow share 700 mm width under different tillage depths with lift angles of 0.26 rad.

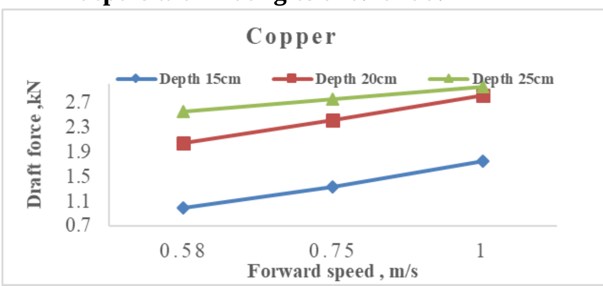

Fig. 5. Draft force vs. forward speed for copper plated chisel plow share 700 mm width under different tillage depths with lift angles of 0.26 rad.

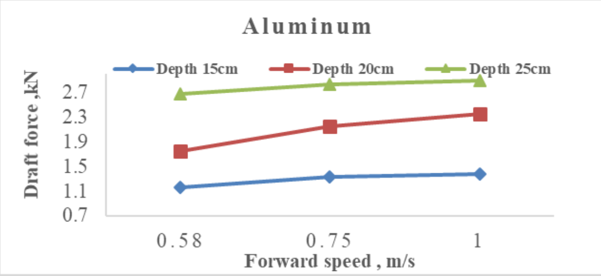

Fig. 6. Draft force vs. forward speed for Aluminum plated chisel plow share 700 mm width under different tillage depths with lift angles of 0.26 rad.

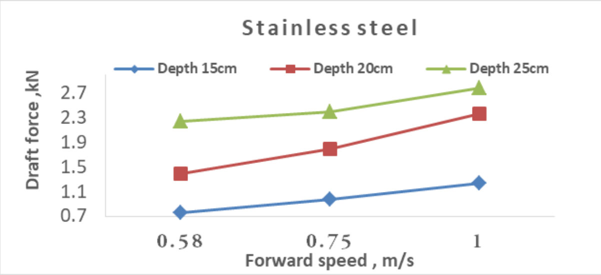

Fig. 7. Draft force vs. forward speed for Stainless steel plated chisel plow share 700 mm width under different tillage depths with lift angles of 0.26 rad.

Comparison of the used tillage tools (chisel plow shares)

At a depth of 15 cm

Fig. 8 shows the relationship between draft force and forward speed at a depth of 15 cm of the tillage tools used (Iron share without coating, Copper plated chisel plow share, Aluminum plated chisel plow share, and Stainless steel-plated plowshare), they have the same geometric dimensions (width 70 mm and lift angle 26 rad).

It is clear from Fig. 8 that the stainless steel-coated share recorded the lowest rates of horizontal force relative to the rest of the shares at all speeds.

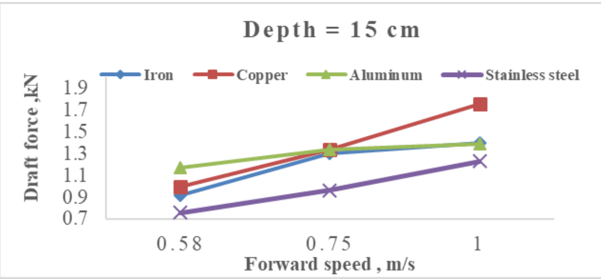

Fig. 8. Draft force vs. forward speed for the tillage tools used at a depth of 15 cm with lift angles of 0.26 rad.

At the first speed of 0.58 m/s, all pull forces were relatively small and close, the highest pull force values recorded with the aluminum-coated shares with a value of 1.17 kN, the iron-coated copper shares recorded very close values. The copper-plated share had a value of 1 kN, while, the iron share horizontal force value was about 0.92 kN and the lowest value was for the stainless-steel coated share with a value of 0.76 kN.

At second speed, the recorded pull force values with the stainless steel-coated share were the lowest, while the other three shares had their values very close to each other. The draft force values for the stainless steel-coated share were about 0.97 kN, while the aluminum-coated share recorded about 1.33 kN, the iron share was about 1.3 kN, and the copper-coated share recorded the highest value about 1.34 kN, which is slightly higher than the previous two shares.

As for third forward speed, 1 m/s, the copper-coated share recorded the highest pull force value of 1.76 kN, and for the rest of the shares at this depth, the stainless share remained the least valuable among them with 1.23 kN recorded pull force value. As for the iron share and the aluminum-coated share, their values were medium and very close; the values of the draft force for the first were about 1.4 kN and for the last about 1.39 kN.

At a depth of 20 cm

Fig. 9 shows the relationship between draft force and forward speed at a depth of 20 cm of the tillage tools used (Iron share without coating, Copper plated chisel plow share, Aluminum plated chisel plow share and Stainless steel - plated plow share, they have the same geometric dimensions (width 70 mm and lift angle 0.26 rad).

At a depth of 20 cm, the draft force values of all shares increased at different speeds due to an increase in the layers of the soil, with more compact, less porous, and higher moisture content, and also the increase in the mass of the plowed soil layer and the increase in the area of land surrounding the share. Stainless steel-coated shares also recorded the lowest values of pull force values. At the first speed, 0.58 m/s, the copper-coated share had the highest reading of the draft force with a value of about 2.04 kN, followed by the iron share, and the difference between them was very slight, as it recorded pull force value of 1.99 kN. As for the aluminum-coated share, it recorded an average value of about 1.76 kN. As for the share Coated with stainless steel, the lowest soil reaction (draft force) was recorded with a value of about 1.38 kN .

At the second speed of 0.75 m/s, the copper-coated share had the highest reading of the draft force with a value of about 2.41 kN, followed by the iron share, which recorded about 2.26 kN, and the aluminum-coated share recorded with an average value of about 2.16 kN, which is the closest to the iron share. Coated share with stainless steel achieved the lowest soil reaction (draft force) and recorded pull force value of about 1.79 kN.

At the third speed, 1 m/s, the copper-coated share also had the highest reading, the draft force was about 2.82 kN, followed by the iron share, which recorded about 2.67 kN, and the stainless steel-coated share had a horizontal force of about 2.36 kN, while, the aluminum-coated share recorded pull force value very close to the stainless steel-coated share, but lower and it was 2.35 kN.

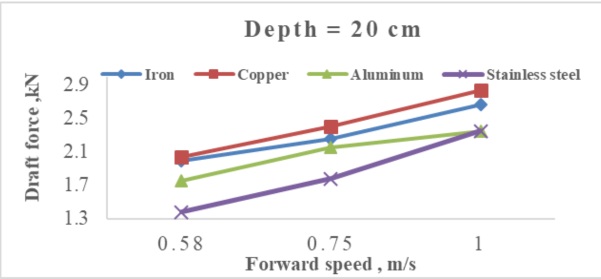

Fig. 9. Draft force vs. forward speed for the tillage tools used at a depth of 20 cm with lift angles of 0.26 rad

At a depth of 25 cm

Fig. 10 shows the relationship between draft force and forward speed at a depth of 25 cm of the tillage tools used (Iron share without coating, Copper plated chisel plow share, Aluminum plated chisel plow share and Stainless steel-plated plowshare, they have the same geometric dimensions (width 70 mm and lift angle 0.26 rad). Here also, at a depth of 25 cm, all readings increased at different speeds for all shares used, due to the same previous reasons.

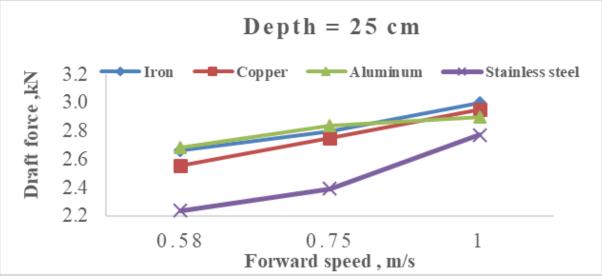

Fig. 10. Draft force vs. forward speed for the tillage tools used at a depth of 25 cm with lift angles of 0.26 rad

The horizontal force at the first speed of the aluminum-coated share was the highest at depth of 25 cm with a value of about 2.68 kN, but it is very close to the value recorded with using the iron share, which recorded a reading of about 2.67 kN, and the copper-coated share recorded a aa little difference in pull force value of 2.56 kN, but it was the least pull force value recorded among the different shares , where, the horizontal force value with the stainless steel coated share was about 2.24 kN.

At the second forward speed, the stainless steel-coated share also recorded the lowest pull force value of about 2.39 kN, while the differences between the other shares were close and the highest was for the aluminum-coated share with a value of about 2.84 kN, followed by the iron share with a draft force of about 2.8 kN, while the copper-coated share achieved horizontal force value of about 2.75 kN.

At the third forward speed, 1 m/s, the draft force value of the iron share became the highest with a value of about 2.99 kN, followed by the copper-coated share with a value of about 2.95 kN with a small difference and a lower value. The aluminum-coated share recorded a reading of the horizontal force of about 2.9 kN. The lowest value was the stainless steel-coated share with a value of about 2.77 kN.

CONCLUSION

It was observed that the maximum value of draft force (2.99 KN) was obtained for iron share at forward speed 1 m/s and tillage depth 25 cm. The minimum value of draft force (0.76 kN) was obtained with using stainless steel-coated share at forward speed of 0.58 m/s and 15 cm tillage depth. It is recommended to coating the plow shares with stainless steel metal, due to the low horizontal force affecting it compared to iron and the rest of the materials used for coating in the experiments, not only for that reason, but also, stainless coating helps to extend the lifespan of the shares by protecting it from rust and corrosion.

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تأثير تغطية اسلحة المحاريث الحفارة ببعض المواد على قوة الشد المطلوبة

أحمد محمد أحمد الشيخة [1] ، محمد علي إبراهيم الراجحي[2] و تحية محمد أيمن الشباسي[1]

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تم اختبار ثلاثة اسلحة مختلفة للمحاريث الحفارة (الأول مغطي بطبقة من النحاس بسمك 2 مم، والثاني مغطي بطبقة من الالومنيوم بسمك 2 مم والثالث مغطي بالاستانلس ستيل بسمك 2 مم) ومقارنتها بالسلاح المصنوع من الحديد الصلب وكان لهم نفس الابعاد الهندسية بعرض 70 مم وزاوية قطع ٤٥ درجة وزاوية اختراق ٢٥ درجة مع الافقى . تم اجراء التجارب بقرية العزازمة بمركز فارسكور بمحافظة دمياط بمساحة حوالي ٥٠٠ م٢ عند محتوى رطوبي للتربة ٢١ %. اجريت التجارب لجميع الاسلحة على اعماق مختلفة هى : (١٥، ٢٠، ٢٥ سم) وعلى سرعات أمامية مختلفة هى : (0.58 ، 0.75 ، 1 م/ث). اتضح من النتائج ان أكبر قوة أفقية (٢,٩٩ ك نيوتن) للسلاح الحديد الغير مغطي عند أكبر سرعة أمامية 1 م /ث وعمق حرث ٢٥ سم وأقل قوة أفقية (٠,٧٦ ك نيوتن) للسلاح المغطي بالاستانلس ستيل عند أقل سرعة أمامية 0.58 م/ث وعمق حرث ١٥ سم. واتضح أن القوة الافقية للسلاح االمغطي بالاستانلس ستيل فى جميع النتائج كان اقل قيمة، مما يترتب عليه أنه يعتبر أفضل الأسلحة المستخدمة فى التجربة من حيث الاحتكاك مع التربة وأنه يعمل على زيادة العمر الافتراضى للسلاح لانه يحميه من الصدأ والتآكل.