PERFORMANCE EVALUATION OF AN ENAMEL COATED ANIMAL DRAWN MOULDBOARD PLOUGH

I.A. Loukanov, J. Uziak

Department of Mechanical Engineering,
Faculty of Engineering and Technology,
University of Botswana, Private Bag UB 0061,
Gaborone, BOTSWANA

ABSTRACT *The power requirement of tillage implements is an important design consideration particularly for animal drawn implement, because of the power limitation of work animals. In this paper, an effort was made to reduce the draft requirements of animal drawn mouldboard plough by using enamel coating on the soil-engaged components such as the mouldboard, share and the landside. Trials were conducted to compare enamel coated BSP (Bulawayo Steel Products Pvt.) mouldboard plough (animal drawn) with similar uncoated plough under similar working conditions. Experiments were conducted at 25% and 32% (db) moisture content on a red clay soil in Zimbabwe. The parameters measured to evaluate the performance of both ploughs were: the tractive effort (pull), speed of ploughing (0.8 m/s, not varied), depth and width of ploughing, and soil conditions (i.e. soil moisture, bulk density and soil hardness). Maintaining the same working conditions it was found the enamel coating reduced the specific draught by 10% to 18% depending upon soil moisture content.*

1. INTRODUCTION

The mouldboard plough has always been the basic tillage implement on the farm. Although historic, it is still useful and widely employed for primary tillage. It cuts the soil slice, lifts it over the surface of the mouldboard and inverts it, burying the surface growth and crop residues to leave a clear surface for subsequent cultivation, or to be weathered into a seedbed (Brassington 1989).

Animal traction is an appropriate, affordable and sustainable technology that is still important throughout Eastern and Southern Africa, complimenting both land labor and tractor power. Therefore, animal traction technology in terms of draft power requirements is a crucial area of research and development. The animal drawn mouldboard plough is widely used for primary tillage in the developing counties of Africa (Inns 1990). It is simply because of its low cost and the availability of work animals such as oxen, cows, donkeys, horses and mules.

2. LITERATURE REVIEW

The draft requirements of an animal drawn mouldboard plough is affected by following factors: the type of soil, soil moisture conditions, speed of ploughing (does not vary significantly), depth and width of the furrow slice, type of mouldboard used, as well as the soil-to-metal friction characteristics of the soil-engaged components. By reducing the soil-to-metal friction, the draft requirement of the plough can be improved considerably. Various efforts have been made to reduce friction and adhesion of soil on tillage implements by using coatings, such as glass, Teflon, and other low friction materials but were unsuccessful due to poor wear resistance, complicated coating techniques or cost limitations. Salokhe and Gee-Clough (1988) tried different coating materials in investigating the soil adhesion on cage wheel lugs. They found that enamel coating on a cage wheel lug reduced the soil adhesion considerably. Later Salokhe et al. (1989) employed enamel coating to mouldboard plough, mainly to mouldboard and share, and conducted experiments under laboratory conditions.

Considering that the enamel coating technique is cheap and readily available, and with the promising results obtained so far, it was decided to carry out similar tests of enamel coating for an ox-drawn plough in field conditions.

3. METHODOLOGY

Experiments were conducted at the Institute of Agricultural Engineering, Borrowdale, Harare, on a red clay soil, which is considered as one of the heaviest soil in Zimbabwe. The enamel-coated BSP mouldboard plough and similar uncoated plough (both animals drawn) were used to plough three test plots of 20 m by 10 m. The plough for each test was set to operate at required depth and width before trials began. The trials for each test were replicated five times maintaining approximately the same working conditions. Before any tests were carried out, the moisture content was determined by using an electronic moisture meter HH1 and soil bulk density calculated employing the core ring method (Table 1). The mineral moisture content was actually determined which approximates the gravimetric moisture content being of our interest. The procedure of taking readings involved taking soil samples up to 30 cm profile depth.

Table 1 Soil Properties

	Trials 07.04.2000		Trials 27.04.2000	
Depth	Bulk Density	Soil Hardness	Bulk Density	Soil Hardness
(mm)	(g/cm3)	(kgf)	(g/cm3)	(kgf)
	Av. for 3 stat.	Av. for 3 stat.	Av. for 3 stat.	Av. for 3 stat.
0 - 50	1.20	0.2	1.03	0.0
50 - 100	1.25	0.3	1.17	0.8
100 - 150	1.18	0.9	1.18	1.5
150 - 200	1.16	1.7	1.38	1.7
200 - 250	1.07	2.0	0.98	1.6
250 - 300	1.07	2.3	1.13	1.5
Average	1.154	1.22	1.147	1.19
Moisture Content (dry basis)	31.76%		24.78%	

During each trial draft was measured by recording the tractive effort (pull) employing a load cell and portable electronic amplifier fitted with a processor giving readings at intervals of 2 seconds. This provided approximately about 10 readings per run. The draft was calculated in accordance with the equation

$$\text{Draft (D)} = [\text{Pull (P)}] \cdot [\cos(\alpha)] \qquad (1)$$

where α is the angle of inclination of the chain to the horizontal (α = 19.5o).
The load cell was attached in between the chain and plough, and connected to the amplifier by means of a cable. In addition, time was taken to plough 20 m length to estimate the average speed of ploughing. Experiments were conducted on two days, at two levels of soil moisture content 25% and 32% (db) and working speed of 2.88 km/h. On each day of the trials both coated and uncoated ploughs were tested, maintaining same working conditions such as set depth and width of cut and soil moisture content. The depth of cut was measured at various points along the furrow, whiles the width of cut was taken as the distance between successive furrow edges. Ploughs were modified on the field by using two pairs of replaceable components. These include enamel coated and uncoated components namely the share, mouldboard and landside.

4 RESULTS AND DISCUSSION

In general, the variation of the ploughing speed was found to be within the range 0.7 - 0.9 m/s giving an average of 0.8 m/s (2.88 km/h). The experimental results were determined at two levels of moisture content.

4.1 Specific Draft Results for 25% Soil Moisture Content.

The specific draft results obtained for coated and uncoated ploughs at 25% moisture content (the experiment was done on 27.04.2000) are shown in Table 2.

Table 2 Specific Draft for Moisture Content 25%

	Uncoated Plough				Enamel Coated Plough			
Trials	Pull Mean Value	Draft Value	Area	Specific Draft	Pull Mean Value	Draft Value	Area	Specific Draft
No.	(N)	(N)	(m2)	(N/cm2)	(N)	(N)	(m2)	(N/cm2)
1	649.6	612.3	0.0360	1.70	606.2	571.4	0.053	1.08
2	677.6	638.7	0.0487	1.31	569.7	537.0	0.049	1.09
3	688.0	648.5	0.0472	1.37	575.8	542.8	0.052	1.05
4	653.8	616.3	0.0449	1.37	560.2	528.1	0.049	1.07
5	625.3	589.4	0.0355	1.66	562.9	530.6	0.045	1.18
Ave.	658.9	621.1	0.0425	1.48	575.0	542.0	0.0496	1.10

The table also includes the mean value of the pull, P and draft D, and the specific draft for five trials. From Table 2 it is evident that the values of the specific draft for the coated plough are lesser than for uncoated plough. The average values of the specific draft for coated and uncoated plough were 1.10 N/cm2 and 1.48 N/cm2 respectively. The percentage reduction in the specific draft was found to be 25.7%. Evidently, the enamel coating on the mouldboard plough reduced the specific draft considerably as compared to uncoated plough at this level of soil moisture content.

4.2 Specific Draft Results for 32% Soil Moisture Content.

The specific draft results obtained for coated and uncoated ploughs at 32% moisture content (the experiment was done on 07.04.2000) are shown in Table 3. These include the mean values of the pull, P, and draft D and specific draft for five successive trials.

Table 3 Specific Draft for Moisture Content 32%

	Uncoated Plough				Enamel Coated Plough			
Trials	Pull Mean Value	Draft Value	Area	Specific Draft	Pull Mean Value	Draft Value	Area	Specific Draft
No.	(N)	(N)	(m2)	(N/cm2)	(N)	(N)	(m2)	(N/cm2)
1	1,394.5	1,314.5	0.0283	4.64	1,142.3	1,076.8	0.029	3.74
2	1,406.5	1,325.8	0.0276	4.80	1,099.4	1,036.3	0.029	3.55
3	1,308.5	1,233.4	0.0229	5.40	1,131.6	1,066.7	0.027	3.92
4	1,355.0	1,277.3	0.0263	4.85	1,176.2	1,108.7	0.027	4.14
5	1,446.9	1,363.9	0.0292	4.67	1,110.4	1,046.7	0.026	4.05
Ave.	1,382.3	1,303.0	0.0269	4.87	1,132.0	1,067.1	0.0276	3.88

In terms of specific draft variation for coated and uncoated ploughs Table 3 shows the same trend as Table 2. The difference is in the larger values of the specific draft obtained at 32% moisture content compared to that at 25%, which constitutes an increase of 3.53 times. This is due to the increased moisture level leading to an increased soil to metal adhesion. As a result of that, the specific draft has increased drastically. The average values of the specific draft for coated and uncoated plough are 3.88 N/cm2 and 4.87 N/cm2 respectively. In terms of specific draft reduction it is found that the percentage reduction is 20.3%. On the other hand, the increase in soil to metal adhesion leads to decreased values of the percentage of specific draft reduction. However, the values obtained for the specific draft reduction (Tables 2 and 3) are very similar to those reported by Solokhe et al. (1989) for mouldboard plough.
Comparison is made between coated and uncoated ploughs in terms of specific draft reduction for five trials and the results are shown in Figure 1. It is observed that the specific drafts at both moisture levels are smaller for coated plough compared to uncoated plough. The decrease in specific draft for enamel coated plough is found to be 25.7% at 25% soil moisture content and 20.3% at 32% as compared to uncoated plough. This can be attributed to the greater difference in soil-metal friction on the ploughs. In addition to that it is noticed that there is a significant difference in the average values of the specific draft at both levels of soil moisture content, which can be attributed to the increased adhesion at higher levels of moisture content.

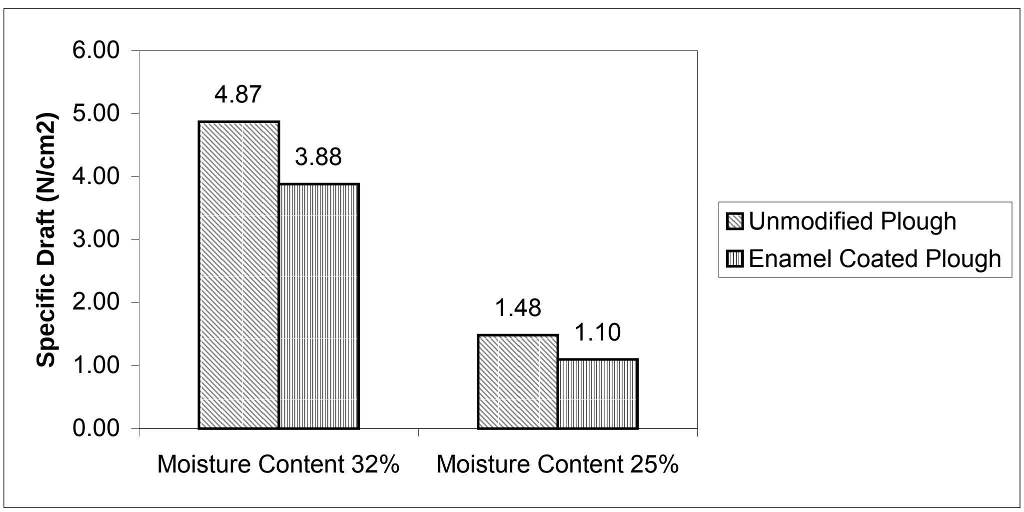

Fig. 1

Figures 2 and 3 show the specific draft variation for enamel coated and uncoated ploughs at 25 % and 32% soil moisture content respectively within the conducted trials.
Figure 2 shows the specific draft variation at 25 % soil moisture content. It is noticed that the specific draft for the coated plough varies from 1.05 N/cm2 to 1.18 N/cm2, whiles that for uncoated plough varies from 1.31 N/cm2 to 1.70 N/cm2, the greatest difference between the two specific drafts being 0.62 N/cm2.

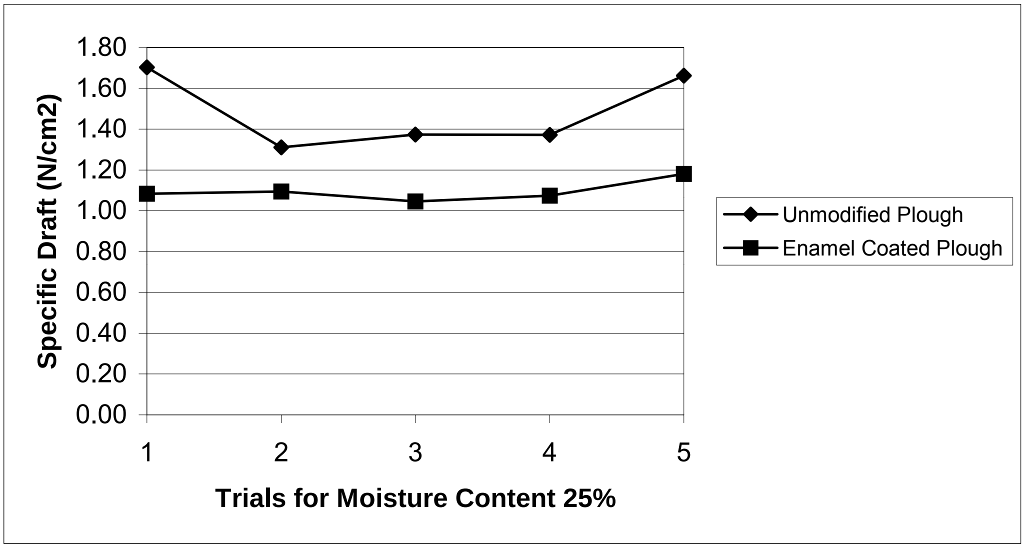

Fig. 2

Similar observations can be made for the 32% soil moisture content (Figure 3), the specific draft for the coated plough varies between 3.33 N/cm2 and 4.14 N/cm2 and for uncoated plough from 4.64 to 5.40 N/cm2, with the greatest difference between both specific drafts being 1.48 N/cm2.

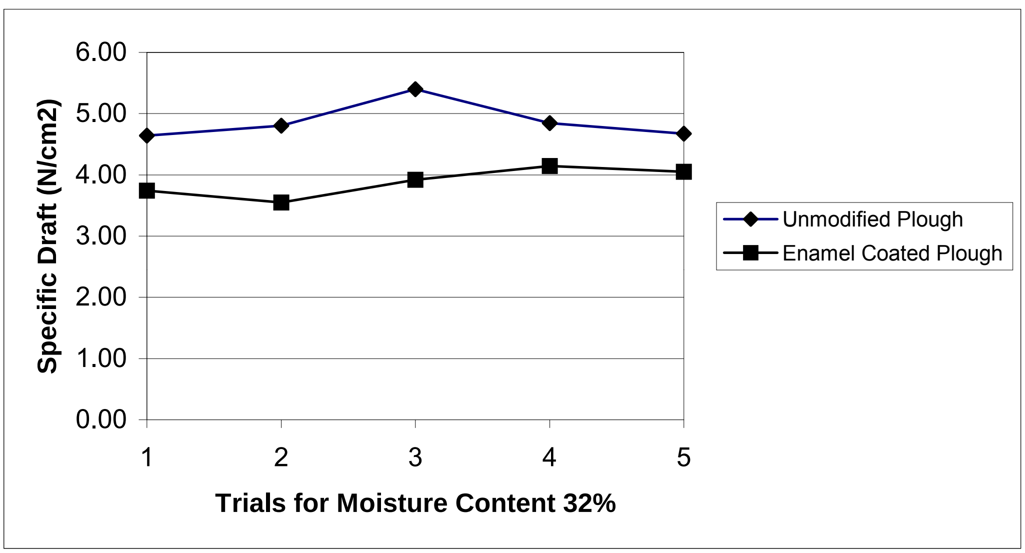

Fig. 3

5. CONCLUSIONS

As a result of the analysis of the experimental results obtained it was found that an enamel coating reduced considerably the specific draft required. As compared to uncoated plough the specific draft was reduced by up to 25.7% depending upon the soil moisture level. Observations were made on the coated surfaces for the existence of any damages, but none were found. This was a preliminary conclusion about the durability of the enamel coating and further investigations are needed to find its durability in practice.

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