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IMPROVEMENT OF THE INDIGENOUS PLOUGH OF WESTERN INDIA.

BY

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APPENDIX I.

It has been stated on page 6 that the plough should be as smooth as possible. The reason for stating this is that a very large proportion of the total force exerted by bullocks is spent in overcoming the friction between the sides of the plough and the sides of the furrow. The proportion of this friction to the total force exerted was arrived at by a laboratory experiment with a small model.

The following are the details of the experiment :—

The weight of the plough	... ..	= 536 grammes.
The distance of the centre of gravity of the plough from the end of the share	... ..	= 2.37 inches.
The weight of the soil standing over the plough	... ..	= 176.6 grammes.
Distance of the centre of gravity of the plough from the end of the share	... ..	= 3.25 inches.

The sum of the moments tending to balance the plough

$$536 \times 2.37 + 176.6 \times 3.25 = 1844.27.$$

I.—Determining the position of the plane along which the resistance acts.

The pull is exerted along a horizontal string attached to the beam which is also kept horizontal. In this case it was found that the plough, instead of being moved through the soil, was raised up from behind when a force of 726 grammes was applied at the end of the string.

At this moment the overturning moment due to the force must be equal to the balancing moment. If in the following figure P represents the pull, R the resistance (R being equal to P) and X the arm of the couple tending to overturn the plough, $P \times X$ will be the overturning moment.

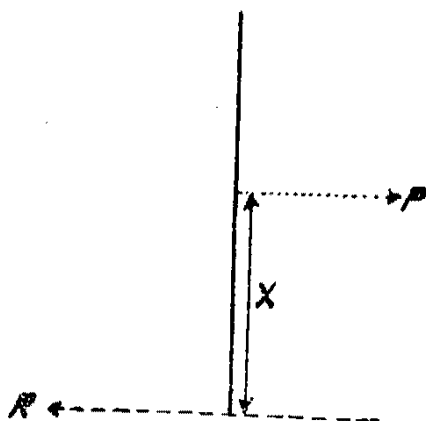


Fig. 6.

As $P = 726$ the overturning moment is $726 \times X$. This is equal to 1844.27 the balancing moment. The arm of the couple therefore is equal to 2.54 inches, *i. e.*, the plane along which the resistance acts is 2.54 inches below the point at which the beam is fixed to the head of the plough.

II.—Determining the total resistance.

The pull is exerted along a horizontal string attached to a nail driven in the plough so that the string should lie in the plane along which the resistance acts. In this case it was found that the plough was perfectly balanced and moved in the soil when the tension on the string was 1,616 grammes. The depth of the furrow in this case is 1.60 inches. The tension on the string represents the total resistance offered to the movement of the plough. The total resistance for every inch of depth excavated is therefore 1,010 grammes.

III.—Determining the resistance due to friction.

The pull is exerted as in I, along a horizontal string attached to a horizontal beam which is 2.54 inches above the plane along which the resistance acts. In this case it was found as in I that the plough was overturned before it began to move. This was clearly due to the fact that the overturning moment was greater than the balancing moment. It was therefore necessary to increase the balancing moment and make it equal to or a little greater than the overturning moment in order that the plough may be perfectly balanced and move in the soil. This was effected by putting a weight on the head of the plough. The distance of the head of the plough from the end of the share was 8 inches. The balancing moment was increased by eight times the weight put on the head of the plough.

A number of experiments was made to determine the exact weight which, when placed on the head of the plough, would balance it while moving in the soil. As a result of these experiments it was found that when a weight of 500 grammes was placed over the head of the plough, it was moved through the soil and was perfectly balanced. The tension on the string was 2,411 grammes and the depth of the furrow was 2 inches. It has been found in II that the total resistance for every inch of depth excavated is 1,010 grammes. The pull in the above instance where the depth of the furrow is 2 inches should have been 2,020 instead of 2,416. This shows an increase of 396 grammes in the total resistance. This represents the frictional resistance caused by the extra pressure of 500 grammes. This shows that for every 100 grammes of the weight of the plough the frictional resistance is 79.2 grammes.

In this case the total weight of the plough is 1,036 grammes and the weight of the soil which increases with the depth of the furrow is 220 grammes. The total pressure is 1,256 grammes. The frictional resistance due to this pressure is 994.75 grammes.

* The total frictional resistance is therefore 41.17 per cent. of the total resistance to be overcome. It is therefore absolutely necessary to diminish this as far as possible by making the surfaces of the plough very smooth.

* It should be noted that the soil taken for this experiment was loose soil and therefore less force had to be exerted to overcome the cohesion of the soil. The percentage of the force of friction is therefore a little greater.

APPENDIX II.

On pages 7 and 8 four different methods of exerting the pull for drawing the plough are given with their respective advantages and disadvantages. Of these the fourth is the one which always occurs in practice, and therefore is important enough to demand an experimental verification with a small model. An experiment was therefore made, of which the following are the details:—

Weight of the plough	...	... = 686 grammes.
Distance of the centre of gravity of the plough from the end of the share	...	... = 4.25 inches.
Weight of the soil over the plough	...	... = 277.86 grammes.
Distance of the centre of gravity of the soil from the point of the share	...	... = 4.83 inches.

The sum of the moments tending to balance the plough
 $= 686 \times 4.25 + 277.86 \times 4.83 = 4258.56.$

I.—Determining the position of the plane along which the resistance acts.

This was arrived at as explained in Appendix I, step I. In the case of this plough this plane is situated at a distance of $\frac{1}{4}$ th inch above the bottom of the plough and 1.5 inches below the point at which the beam is fixed to the head of the plough.

II.—Determining the total resistance.

This was obtained as explained in Appendix I, step II. In the case under consideration the total resistance was 1,488 grammes when the depth of the furrow was 2 inches and its breadth at top is 3.5 inches. The sectional area of the furrow opened is 3.5 square inches and therefore the resistance per square inch of furrow opened is 425.14 grammes. In this case the resistance being equal to the pull, the pull is also 425.14 grammes per square inch of furrow opened.

III.—Effect of applying the force as explained in method (4), page 8.

The pull was exerted along a string fixed to a beam which slopes upwards. The inclination of the beam to the horizontal was gradually increased until the maximum inclination, at which the plough could be balanced and worked, was obtained. This inclination or slope was 2 inches in 12.5 inches. The vertical component of the pull is $\frac{2}{12.5}$ or .16 of the total pull. Under these circumstances the plough could be worked with a pull of 1,639 grammes along the string. The depth of the furrow was $1\frac{3}{4}$ inches and its breadth at top was 3.5 inches. The sectional area of the furrow was 3.28 square inches. The horizontal component of the pull which only is useful in working the plough is 1,367 grammes or 416.77 grammes per square inch of furrow opened. This is almost the same as the pull required for doing the same work when the pull was exerted along the plane along which the resistance acts.

In this case the overturning moment is

$$272 \times 7.25 + 1367 \times 1.5 = 4022.5$$

and the balancing moment is 4082.52. Both these are almost equal to one another.

It was further found that when the inclination of the beam was made steeper than this the plough could not be balanced and worked.

The statement made in method (4), page 8, is thus clearly proved by this laboratory experiment.

APPENDIX III.

This is intended to illustrate the way in which the actual pull exerted by the bullocks is determined from the recorded readings of the dynamometer.

In Fig. 5, page 8, A and B represent the yokes. GA and FB represent the chains along which the dynamometers are placed. The positions of the dynamometers are also shown in the figure.

The heights of F, B, G and A were measured from the ground and the lengths of GA and FB were also measured.

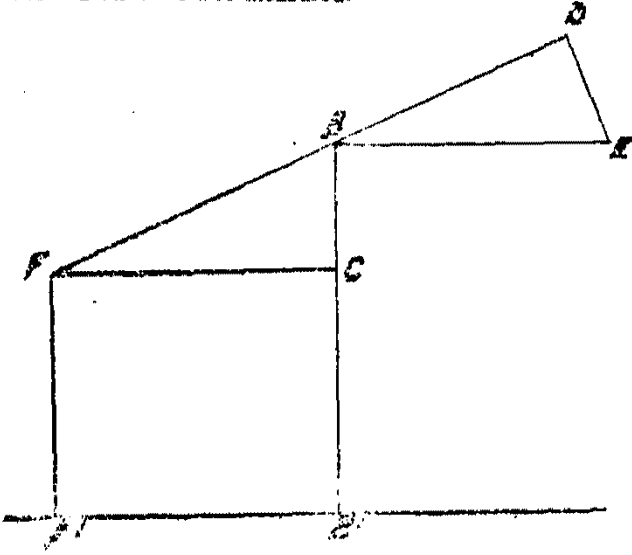


Fig. 7

In the above figure FF' and BB' represent the heights of F and B above ground.

$BC = BB' - FF'$ and FB was actually measured.

Therefore the angle BFC of the right angled triangle BCF could be determined. The angle $BFC =$ the angle DBE . BE represents the direction in which the pull is exerted by the bullocks. We want to find the relation between BD and BE , *i.e.*, between the tension on the chain which was given by the reading on the dynamometer and the actual pull exerted by the bullocks.

$$\cos DBE = \frac{BD}{BE} \quad \text{Therefore } BE = \frac{BD}{\cos DBE}$$

The actual pull exerted by the bullocks is equal to the reading on the dynamometer divided by the cosine of the angle made by the chain with the horizontal.

The same method is adopted in calculating the pull due to the tension on the chain GA.

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