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Analysis of the Application of Gorjatchkin and Gee Clough Models for the Predicting the Two Shapes of Ploughshare Efforts

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Abstract: The evaluation of the draft which the sol opposes, with its physical and mechanicals properties, to the advance of a body of share plough is the several research task object whose results lead to the presentation of several mathematical models. These models often introduce the properties of the soil, particularly its specific resistance and its density. The analysis of these models shows that the geometrical characteristics of active surfaces are however not taken into account. The objective of this study is the choice of the model to be used for an evaluation of the draft has an importance when the precision of calculation is required. For that 2 models were selected. The first is that proposed by Gorjatchkin, the second one is proposed by Gee Clough. The relations between measured and calculated effort are: Ft_{Enpma} = 5.05 + 1.72. FtGee -0.72. FtGor and Ft_{Sacra} = -18.79 + 0.24.FtGee + 1.46. FtGor.

Key words: Effort, Gorjatchkin model, Gee Clough model, ploughshare, form

INTRODUCTION

One of the concerns of farmers is assessing the energy consumption for a given culture establishment. For that several methods are proposed, among them we retain that of the full tank which is a direct method but few precision and the evaluation of the effort. This latter method is chosen for our work.

In recent years several mathematical models have been developed to predict the characteristics and performance of the Ploughing tools and their actions on the soil. These models are of two types. The first 2-dimensional and concerns the so-called simple tools such as blades and Tines and the second type 3-dimensional, is on the complex surfaces tools such as ploughshare.

In general validity of these models has been established by comparing predictions with experimental results usually obtained with channel traction.

Several authors have studies the problem of assessing the effort which soil to the tool ploughing advancement. Following this work several mathematical models have been proposed. We Examples include, among other, Binesse (1970), Oskoui *et al.* (1982) and Qiong Gao *et al.* (1986) models. For their simplicities, most models used to calculate the efforts are as Gorjatchkin and Gee Clough models.

$$Ft = fG + kab + \varepsilon abv^2 \text{ (Gorjatchkin)}$$

For the current plows that are brought, the first part (f.G) Gorjatchkin model, will be neglected, therefore we will retain for our calculations:

$$Ft = kab + \varepsilon abv^2$$

$$Ft = ab\left(13.30\gamma a + 3.06\gamma \frac{v^2}{g}\right) \text{ (Gee Clough)}$$

Both models introduce depth (a) and width (b) ploughing, the speed and soil characteristics; for Gorjatchkin is the specific resistance of the soil (k) hand Gee Clough introduced soil bulk density (γ). Gorjatchkin introduced a shape parameter (ε) of surfaces, which is often very difficult to determine, because its values are between 1500 and 2000 daN s^2 m^{-4}.

MATERIALS AND METHODS

To highlight the effect of the active areas shape on the effort, the trials were conducted on a traction channel with a reduced model of ploughshare to scale a half, 2 bodies plough shovels manufactured in Algeria, shape and form SACRA ENPMA (Table 1). The reasons for this choice are seeking control of the physical and mechanical

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Table 1: Geometric characteristics of the two reduces models of plough

Corps de charrue	ENPMA	SACRA
Ploughshare shape	Trapezoidal	Trapezoidal
Height h (mm)	220	218
Projected length l (mm)	470	460
Width b (mm)	150	150
Angle α (°)	29	17
Angle γ (°)	38	39
Angle θ (°)	35	33
Angle β (°)	40	48

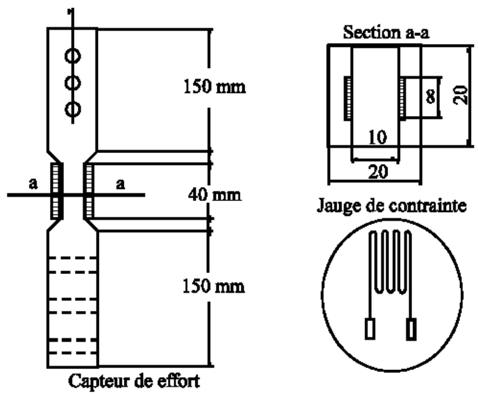

Fig. 1: Sensor effort

characteristics of soil to avoid interaction of these effects on the effort. Efforts on canal test were determined with precision using extensiometriques sensors effort (Fig. 1).

Conditions of work:

- Dry bulk density of the soil: d_a = 150 kN m^{-3}.
- Specific Resistance of soil: k = 18000 N m^{-2}.
- Width of work ploughing is the same and is: b = 0.15 m.

Three depths of work have been selected, they are respectively a = 0.07, 0.09 and 0.12 m.

In calculating effort with the Gorjatchkin model we took 2 values of ε, the first 1500 Ns^2 m^{-4} for SACRA form which is cylindrically shaped and 1750 Ns^2 m^{-4} for ENPMA form which has tendency cultivation.

The change in form factor is not very significant to the value of a calculated effort with the Gorjatchkin model, in fact, the conditions of our tests, if we consider the effort calculated to a depth of 0.12 m and the speed of 0.15 m.s^{-1} and the variation of ε from 1000 Ns^2 m^{-4}-2000 Ns^2 m^{-4}, the variation of the effort will be 32.44-32.48 daN. This variation is the same for both types of surfaces. The choice of this coefficient value will therefore, not have a great effect on the analysis.

RESULTS AND DISCUSSION

The results of the efforts measured on canal test and calculated using the Gorjatchkin and Gee Clough models are listed on the Table 2 and 3.

Table 2: Comparative values measured efforts and calculated with Gorjatchkin and Gee Clough model for SACRA shape

Ft (daN)	a(m)	v(m.s^{-1})	ε(Ns^2 m^{-4})	FtGOR (daN)	FtGEE (daN)
11.85	0.07	0.04	1500	18.90	14.67
13.2	0.07	0.05	1500	18.90	14.68
12	0.07	0.07	1500	18.91	14.69
12.5	0.07	0.15	1500	18.94	14.77
22.44	0.09	0.04	1500	24.30	24.25
21.52	0.09	0.05	1500	24.31	24.25
2.2	0.09	0.07	1500	24.31	24.27
24.12	0.09	0.15	1500	24.35	24.38
41.11	0.12	0.04	1500	32.40	43.11
40.79	0.12	0.05	1500	32.41	43.11
38	0.12	0.07	1500	32.41	43.13
35.98	0.12	0.15	1500	32.46	43.28

Table 3: Comparative values measured efforts and calculated with Gorjatchkin and Gee Clough model for ENPMA shape

Ft (daN)	a(m)	v(m.s^{-1})	å(Ns^2 m^{-4})	FtGOR (daN)	FtGEE (daN)
13.55	0.07	0.04	1750	18.90	14.67
11.8	0.07	0.05	1750	18.90	14.68
12.1	0.07	0.07	1750	18.91	14.69
29.3	0.07	0.15	1750	18.94	14.77
33.28	0.09	0.04	1750	24.30	24.25
27.5	0.09	0.05	1750	24.31	24.25
26.26	0.09	0.07	1750	24.31	24.27
30.49	0.09	0.15	1750	24.35	24.38
54.6	0.12	0.04	1750	32.40	43.11
55	0.12	0.05	1750	32.41	43.11
55.4	0.12	0.07	1750	32.41	43.13
59	0.12	0.15	1750	32.46	43.28

Comparative analysis of the measured and calculated values of effort: The first observations show that the efforts are similarly calculated values for each model, whichever are higher for the Gee Clough model. The measured values of channel traction are different from those calculated and most important for the ENPMA shape. It therefore, appears that the choice of model for the evaluation the effort must be done in conjunction with the active surface shape.

The analysis of these curves (Fig. 2) shows that in the first depth, efforts measured on channel are lower than those calculated using the models. For the second depth calculated efforts are the same as those measured for the ENPMA form and are higher than those calculated and measured for the SACRA form. For the third depth, it is noticeable that the measured values for the ENPMA form are more important and those measured for SACRA and are higher than the values calculated by Gorjatchkin model. In order to correctly select the appropriate model for the assessment of the effort, a statistical analysis of the results is carried out.

Correlations analysis between calculated and measured efforts: The values of the correlation coefficient (r) between the measured efforts on channel and those calculated using the Gorjatchkin and Gee Clough models

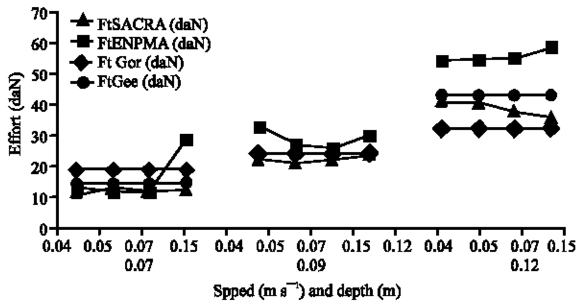

Fig. 2: Variation of the measured and calculated effort within speed and depth

Table 4: Correlation matrices between different values of efforts

	Ft_{Enpma}	FtGee	FtGor	Ft_{Sacra}
Ft_{Enpma}	-	-	-	-
FtGee	0.9631	-	-	-
FtGor	0.9594	0.9974	-	-
Ft_{Sacra}	0.9493	0.9907	0.9919	-

Table 5: Multiple regression analysis: Ft_{Enpma} = f (FtGor, FtGee)

Variable to explain: FtEnpma

Parameter	Estimation	Error	Probability
Constante	5.049	47.838	0.9183
FtGee	1.726	1.807	0.3643
FtGor	-0.725	3.848	0.8546

R^2 = 92.77 %: R^2 ajuste = 91.17%

Table 6: Variance analysis Ft_{Enpma} = f (FtGor, FtGee)

Source	Sum of square	dll	Mean square	F	Probability
Modèle	3225.03	2	1612.51	57.81	0.0000
Résidu	251.02	9	27.89		
Total (Corr.)	3476.05	11			

Table 7 : Regression multiple analysis Ft_{Sacra} = f (FtGor, FtGee)

Variable to explain: Ft_{Sacra}

Paramter	Estimation	Error	Probability
Constante	-18.793	14.491	0.2269
FtGee	0.240	0.547	0.6709
FtGor	1.461	1.165	0.2415

R^2 = 98.42%: R^2 ajusté = 98.07%

Table 8 : Variance analysis Ft_{Sacra} = f (FtGor, FtGee)

Source	Sum of square	dll	Mean square	F	Probability
Modèle	1438.54	2	719.27	281.04	0.0000
Résidu	23.03	9	2.56		
Total(Corr.)	1461.57	11			

are represented in the Table 4. The analysis of the Table 4 shows, a very good correlation between the values of the efforts.

Establishment of relations between the calculated and measured efforts: In order to analyse the order of importance of the link between the measured values and those calculated with models, we chose the method of multiple regressions for each of efforts measured for the 2 shapes surfaces. Table 5 and 6 represent the results of the analysis in the form ENPMA, Table 7 and 8, those of the form SACRA.

Table 5 shows the results of the model adjustment of multiple linear regressions to describe the relationship between the two FtEnpma and explanatory variables FtGor and FtGee. The adjusted equation model is:

$$Ft_{Enpma} = 5.049 + 1.726\ FtGee - 0.725\ FtGor$$

As the value of probability in Table 6 is below 0.01, there was a highly statistically significant relationship between the variables at the 99% confidence.

To determine whether the model can be simplified, noted that the greatest probability value for the explanatory variables is 0.8546 and is associated with FtGor. As the value of the likelihood is greater than or equal to 0.10, calculated effort with the Gorjatchkin model is not statistically significant at the confidence level of 90% or more. Thus, we can consider removing FtGor from model. This means that for the body of ENPMA plough, the model Gee Clough will be chosen for the values of the effort closer to reality.

Table 7 shows the results of the adjustment of a model to describe the relationship between the two FtEsacra and explanatory variables FtGor and FtGee. The equation of the obtained model is:

$$Ft_{Sacra} = -18.793 + 0.240\ FtGee + 1.461\ FtGor$$

Like the previous case, the value of probability in Table 8 is less than 0.01, there is a statistically significant relationship between the variables at the 99% confidence. On the other side, the probability values in Table 7, Gorjatchkin model will be used for assessing the effort required by the form SACRA.

CONCLUSION

Apart from the model Kuczewski (1978), the other models are based on the principle of pressure tool/soil. This principle remains valid for planes surfaces, which are described as simple forms, but is not working for complex surfaces parts such as ploughshare.

Several important research works (Nichols and Kummer, 1932; Doner and Nichols, 1934; Gao *et al.*, 1986), has been made to describe the active surface and classify the forces generated during the performance of the ploughing as well as the relationship of these forces with the dynamic of the soil properties.

Several models predicting the effort (Larson *et al.*, 1968; Gee Clough *et al.*, 1978) were therefore developed on the basis of dimensional analysis. Oskoui *et al.* (1982) proposed a specific model by adjusting the formula developed by Gorjatchkin and Sohene (1960), taking into account the effect of the angle (α) of inlet cone index soil as a base for measuring the force.

If the angular characteristic part working implements simple tools like tines have been the subject of an analysis of their impact on the effort by Desbiolles *et al.* (1997), the geometric characteristics of Surface bodies to ploughshare have rarely been the subject of such work.

If the angles and dimensions of the active areas of the body to ploughshare were studied, it is only within the framework of the description of these parts working or in that of their impact on the qualitative indices (Ross *et al.*, 1995), their effects on the effort, however, has not been studied. Through the results of our work, it appears that:

- The measured values are different from the values calculated with Gorjatchkin and Gee Clough models.
- The values of efforts obtained with the Gorjatchkin model are greater for the first depth (0.07 m) than those obtained with the Gee Clough model.
- At the second depth (0.09 m), the efforts values are the same for the 2 models.
- At the third depth (0.12 m), efforts are more important when they are calculated with the Gee Clough model.

On the other side, when the accuracy of energy consumption is sought, the choice of model used to calculate the effort should be given special attention.

In our case, for the plough manufactured in Algeria, we advocate the Gorjatchkin model for the SACRA form and Gee Clough model for ENPMA form. In a general way for cylindrical form we tend to use the Gorjatchkin model and for the cultivation form, we advise the Gee Clough model.

Finally, for an accurate assessment of operations tillage energy consumption, it will be interesting to establish mathematical models of the effort, taking into account, in addition to the physical and mechanicals properties of soil, geometric characteristics of the working parts, including angular.

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