DERIVATION OF A MATHEMATICAL MODEL TO DESCRIBE THE THRESHING PROCESS FOR DIFFERENT CROPS

BY

Omran Musa Abbass [1], **Hassan Ibrahim Mohamed** [2] **and Omer Mohamed Eltom Elshami** [3]

1- Sudanese Agricultural Council. 2- Department of Agriculture Engineering, Faculty of Agriculture Studies, Sudan University for Science and Technology. 3-Department of Agriculture Engineering Faculty of Agriculture, University of Khartoum.

ABSTRACT

A mathematical scheme based on the continuity equation was made to predict the optimum cylinder-concave clearance in a model of grain thresher for different crops, the output from model machine was compared with a mathematical model. The comparative study indicates no significant difference in the results obtained by the two models .The model for predicting the concave – cylinder relation can be used to aid the design and operation of multi-crop thresher.

الملخص:

تم تصميم نموذج رياضي يعتمد على معادلة الاستمرارية لحساب المسافة بين أسطوانة الدرس والصدر (الخلوص) في موديل دراسة حبوب لمختلف أنواع المحاصيل. تم مقارنة النتائج التي يعطيها النموذج الرياضي مع نتائج نموذج الدراسّة المصنعه محلياً. أثبتت نتائج المقارنة عدم وجود فرق معنوي بين نتائج النموذجين, عليه يمكن استخدام النموذج الذي يحدد العلاقة بين الأسطوانة والصدر في تصميم وتشغيل دًراسة لتحصد محاصيل متنوعة.

INTRODUCTION

Agriculture is the one of the most important sector in the Sudan economy. It employs 70-80 % of the labour force especially at the time of harvest in the both rain fed area and irrigated sector. It supplies the population with basic food needs and provides the import sector with the necessary row materials.

Statistical data of combine import to the Sudan indicates that the total available machine number is less than the number required to harvest the crops at their optimum time. Shortage in the number of harvesters may be due to econo-mic constraint, low maintenance levels and improper machine replacement policies (AOAD, 1993).

The case can be evidenced by the variety of makes and types of combine harvester imported to the Sudan. Moreover, it can be visualized by the timing of the viscous cycle of new death state of large number of harvesters, and the renewal of the number of the harvesters by importation. Hence, the main objectives of this study are:

1- To develop a theoretical model to predict the optimum cylinder concave relation for different crops.
2- To physically evaluate the developed theoretical model for multicrops in comparison with a prototype simulation model machine.

MATERIALS AND METHODS

The threshing process depends upon the concave and cylinder action. The setting of cylinder – concave vary considerably, so the ideal concave is the one that produces an essentially perfect threshing with optimum separation of grain, and at the same time minimizes grain damage.

The idealized threshing mathematical treatment process was subject to the following assumptions:

1- The process is in steady state and the velocity of the moving material is taken as weighted average of the velocities of the various constituents in the element.
2- The cross – sections are uniform.
3- The material to be threshed is homogenous.
4- The passing material is compact and obeys the equation of conservation of mass over smallest time to complete one cylinder revolution.
5- The effects of momentum of the moving elements and the constant pressure impact on the element and the difference in frictional coefficient at the cylinder and concave are ignored and taken indirectly through the consideration of the material density via a correction factor.

The schematic diagram of the cross-section of the cylinder and concave is given in (Fig. 1).

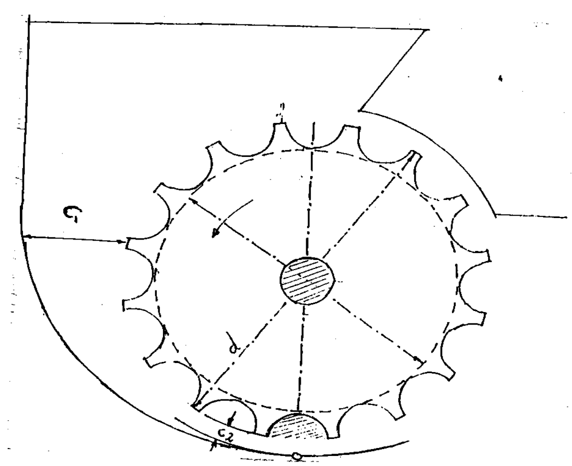

Fig. (1): Schematic Diagram of the Cross-section of the Cylinder and Concave Area

When the cylinder turns one revolution the material flows in and out of its various boundaries as shown in (Fig. 2).

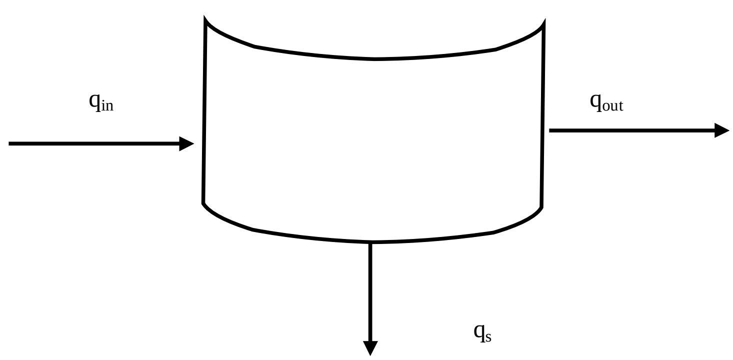

Fig. (2): Representation of the Material through the Concave

The weight of the material sink (threshed material) can be determined by the continuity equation:

$$q_{in} - q_{out} = q_s \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where:

q_{in}: weight of material feeding in.

q_{out}: weight of material passing out.

q_s: weight of material flowing through concave.

From equation (1):

$$q_{in} = Vdn_{in} \times \delta_{in} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where:

Vdn_{in}: volume of material feeding in one revolution

δ_{in}: The bulk density of material.

To determine the volume of material (Vdn_{in}):

$$Vdn_{in} = Vo_{in} + Va_{in} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where:

Vo_{in}: volume of material in concave.

Va_{in}: volume of material in clearance space.

Hence:

$$Vo_{in} = f_{o\,in} \times Z_{in} \times L \times \delta_{in} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Where:

$f_{o\,in}$: cross - sectional area of cylinder area feeding (cm^2).

Z_{in}: number of the cylinder bars.

L: length of cylinder (cm).

δ_{in}: the bulk density of material feeding (volume factor).

The cross - sectional area ($f_{o\,in}$) can be predicted from:

$$f_{o\,in} = \frac{\pi\{(r'_2)^2 - (r'_1)^2\}}{z_{in}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Where:

r'_2: longest point from the cylinder center (cm).

r'_1: shortest point from the cylinder center (cm).

(Fig. 3) shows the flow of material through the cross – sectional area of input and output.

The volume of material in clearance space (Va_{in}) can be calculated as follows:

$$Va_{in} = \frac{\pi}{2 \times c_1(d + c_1) \times L \times \delta_{in}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

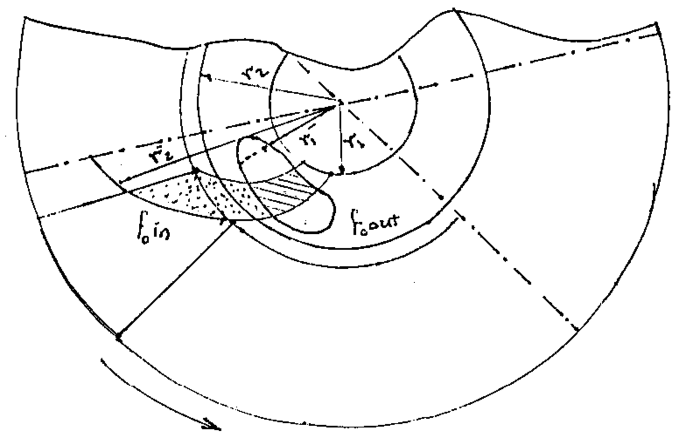

Fig. (3): Schematic Cross –Section of Input and Output Area.

Where:

c_1: rear concave clearance (cm).

Hence, the general volume balance formula of feeding material:

$$q_{in} = f_{o\ in} \times Z_{in} \times L \times \delta_{in} + \pi/2 \times c_1(d+c_1) \times L \times \delta_{in} \qquad \ldots\ldots\ldots\ldots (7)$$

By rearranging equation (7):

$$q_{in} = L \times \delta_{in} \{f_{o\ in} \times Z_{in} + \pi/2 \times c_1(d+c_1)\} \qquad \ldots\ldots\ldots\ldots (8)$$

Similarly the material passing through the concave (q_{out}) is:

$$q_{out} = V_{dout} \times \delta_{out} \qquad \ldots\ldots\ldots\ldots (9)$$

Where:

V_{dout}: volume of material passing out (cm^3).

δ_{out}: The bulk density of material (kg/ (cm^3).

Hence,

$$q_{out} = f_{o\ out} \times Z_{out} \times L \times \delta_{out} + \pi/2 [\times c_2(c_2 + d) \times L \times \delta_{out}] \qquad \ldots\ldots\ldots (10)$$

Where:

Z_{out}: number of concave begs.

c_2: front concave clearance.

$f_{o\ out}$: cross – sectional area of concave output (cm^2).

The cross - sectional area ($f_{o\ in}$) can be predicted from:

$$f_{o\ out} = \frac{\pi\{(r_2)^2 - (r_1)^2\}}{z_{out}} \qquad \ldots\ldots\ldots\ldots (11)$$

From equation (10):

$$q_{out} = L \times \delta_{out} \{f_{o\ out} \times Z_{out} + \pi/2 \times c_2(c_2 + d)]\} \qquad \ldots\ldots\ldots\ldots (12)$$

The volume of material sink (q_s) can be determined by:

$$q_s = f_{os} \times Z^{-} \times L^{-} \times \delta_s \qquad \ldots\ldots\ldots\ldots (13)$$

Where:

f_{os}: cross - sectional area of the pan concave (cm^2).

Z^-: number of openings in the pan concave

L^-: length of concave (cm).

δ_s: density of material blown down ($kg/(cm^3)$).

The general equation can be found by summing all the terms defined in equation (1) as follows:

$$[L \times \delta_{in} \{f_o \times Z_{in} + \pi/2 \times c_1(c_1 + d)\}] - [L \times \delta_{out} \{f_{o\,out} \times Z_{out} + \pi/2 \times c_2(c_2 + d)\}] = f_{os} \times Z^- \times L^- \times \delta_s \quad \ldots\ldots (14)$$

Since the length of the cylinder is assumed to be equal to concave length. Then: $L = L^-$

Therefore:

$$\delta_{in} \times f_{o\,in} \times Z_{in} + \delta_{in} \times \pi[2 \times (c_1)^2] + \delta_{in} \times \pi[2 \times c_1 \times d] - \delta_{out} \times f_{o\,out} \times Z_{out} + \delta_{out} \times \pi[2 \times (c_2)^2] + \delta_{out} \times \pi[2 \times c_2 \times d] = f_{os} \times Z^- \times \delta_s \quad \ldots\ldots (15)$$

By rearrangement

$$\delta_{in} \times f_{o\,in} \times Z_{in} - \delta_{out} \times f_{o\,out} \times Z_{out} + \delta_{in} \times \pi[2\,(c_1)^2 + c_1 \times d] + \delta_{out} \times \pi[2\,(c_2)^2 + c_2 \times d] = f_{os} \times Z^- \times L^- \times \delta_s \quad \ldots\ldots (16)$$

The solution of the above equation determines the optimum concave cylinder clearance (c). This clearance is to be taken as an average value.

In the same way the percentage of the volume of the material flowing through the concave and out of it can be approximated as:

$$V_{in}\,\% - V_{out}\,\% = V_s\,\% \quad \ldots\ldots (17)$$

Therefore, the average concave cylinder clearance can be determined from equation (1) to (17).

DATA COLLECTION

A prototype thresher model was developed and constructed for the purpose of evaluating the performance of multi-purpose thresher by (Abbas, 2002). The prototype model was used to generate input data for validation of the mathematical model. The machine model (Fig. 4). Comprise a power drive unit (electrical motor with two speeds), threshing unit and cleaning unit. Threshing unit consists of drum type stripper bar, concave and drum. The Concave shape is equipped with two point adjustments in the front and rear parts of the concave. Cleaning unit consists of a chaff blower, powered from threshing drum by two pulleys and belt. The blower on two points through drive and driven pulleys powers the Shaker. The Seed collector is located at the rear bottom of the model machine. All these units were mounted on one frame.

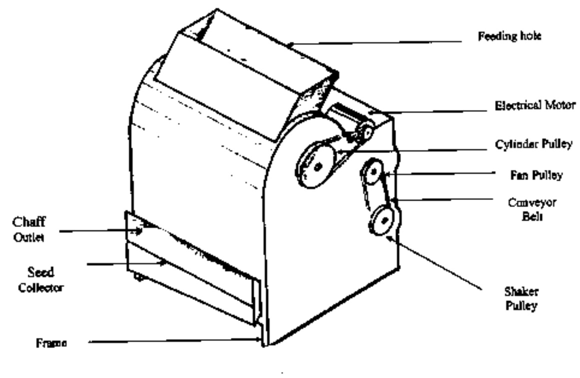

Fig. (4): The Machine Model

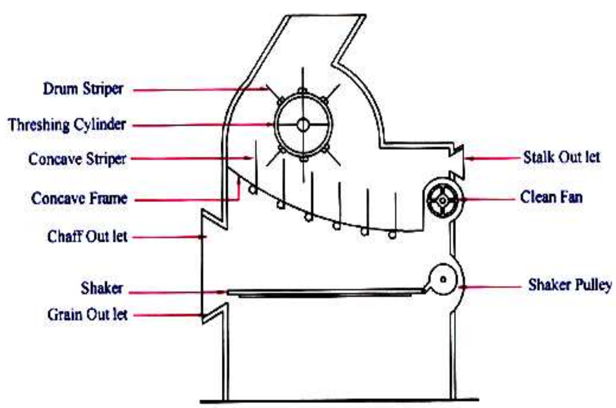

Fig. (5): The Drum and Concave Unit

RESULTS AND DISCUSSION

The mathematical model was applied for the three clearances levels used in the machine model (30, 25 and 15 mm). The inputs are given in (Table 1). The methodologies of calculation of the input are given in equation (1) to (16), and the results of calculation are given in (Table 2). The data was taken from the complete randomised design experiment (model machine) arranged and given in (Table 3). The storage efficiency as given by (Hunt, 1968) can be calculated as:

$$\frac{\text{Storage volume}}{\text{Input volume}} = \text{Throughput}$$

Table (1): The Input Data Mathematical Model

Clear Level (m m)	Front Clear (mm)	Rear Clear (mm)	Volume input (m m)	Volume output (m m)	cylinder length (m m)	concave length (m m)	Volume input Factor	Volume output Factor	Internal Cylinder Dia (mm)	External Cylinder Dia (mm)	Volume input area (mm^2)	Volume output Area (mm^2)
Symbol	C_1	C_2	V_{in}	V_{out}	L	$\bar{L}$	δ_{in}	δ_{out}	D	r	F_{in}	F_{out}
30	35	25	-	-	800	800	-	-	250	286	-	-
25	20	30	-	-	800	800	-	-	250	270	-	-
15	15	15	-	-	800	800	-	-	250	205	-	-

Clear = clearance

Table (2): Thoughput Efficiency from Mathematical Model

Clearance (mm)	Volume (input-output) (mm^3)	Volume Storage (mm^3)	Throughput Efficiency%
30	341043-168160	172883	50
25	102573-71736	308378	30
12	782384-58127	722425	38

Table (3): Thoughput Efficiency from Field Experiment

Clearances (mm)	Weight input (Kg)	Weight Storage (Kg)				Weight output (Kg)	Throughput Efficiency %
		Threshed Pods (Kg)	Un-threshed Pods (Kg)	Pods with chaff (Kg)	Total pods (Kg)		
30	250	105	66	21	142	108	56
25	250	130	51	36	147	103	58
12	250	84	23	26	133	117	52

This efficiency was used as an indicator to compare the mathematical results (Table 2) with the field results (Table 3). Hence, it is evident that the model results are almost typical to the field results. The optimum clearance size was found to be (25 mm) to give a high threshing efficiency in field experiment. In contrast, (Table 3) indicates that clearance (30 mm) is the optimum clearance. However, by using Chi-square test the efficiency obtained under (30 mm) clearance is not significantly different from that obtained by (25 mm) clearance as given in.

CONCLUSIONS

A mathematical scheme based on equation of continuity was made to predict the optimum cylinder – concave clearance for different crops. The output from the mathematical model was compared with that generated from the locally made thresher. The comparative study indicated that there is no significant difference in the results obtained by the two models. Therefore, the mathematical model for predicting the relation between the cylinder and the concave can be used to aid design and operation of multi-crop thresher. Hence to obtain a high threshing efficiency for groundnut crop it is recommended to employ (30 mm) cylinder – concave clearance.

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