OPTIMUM ENGINEERING AND ECONOMIC SELECTION OF ROTARY CULTIVATORS FOR CITRUS ORCHARDS.

II- PERFORMANCE OF POWER-DRIVEN MOTARY CULTIVATORS

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ABSTRACT

Some investigations have been carried out on a (MAB) rotary cultivator to study the effect of some factors on its performance. These factors are the depth of cut and drum rotary speed.

Some of the performance parameters to be considered in this work are the power and specific energy per unit mass of soil on the rotor drum.

It has been found that the power requirements increase with both the depth of cut and drum rotary speed. Whereas, the specific energy per unit mass of soil decreased with depth of cut and increased with drum rotary speed.

1 - INTRODUCTION:

Power-driven rotary cultivators have been recently introduced into the Egyptian agriculture. They have been imported to replace the decreasing hand labour.

Such machines should be tested to adapt it to the Egyptian environment, the performance of these rotary cultivators is affected by many factors, amongest of which is the depth of cut and drum rotary speed. Let alone the factors related to the soil which will not be considered in this work. The type of the soil is clay loam.

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However, the most prominent factors to be studied are: 1) depth of cut, 2) The drum rotary speed. The performance parameters are the drum torque and the power requirements. It may be, thus possible, in the light of such study, to carry out any necessary alterations to adapt the imported rotary cultivators to the local Egyptian Environment.

2 - REVIEW OF PREVIOUS WORK:

Performance of a power-driven rotary cultivator depends to great extent on the kinematics and geometry of cutting operation. Then the study of kinematics and geometry of rotary-cultivation operation makes its possible to have more control over it to obtain the required best results.

Regarding this point, Hendrick and Gill[1] indicated that any point on the periphery of an individual blade describes a trochoidal path. The shape of the soil slice cut is remarkably affected by direction of rotation with respect to forward speed. They derived a formula for determining the increment of cut as given in equation (2-1) below.

$$B = \frac{2\pi R}{\mu . n} \qquad \text{..............(2-1)}$$

where,

- B = increment of cut,
- R = rotor drum radius,
- μ = peripheral-to-forward speed ratio,
- n = number of blades.

Some performance parameters such as soil pulverization and breakup fuel consumption and energy requirements are the prominent parameters for rotary cultivation operation.

As far as soil resistance is concerned, Turner[2] pointed out that the nature of soil and moisture content are the important factors according to which tilling methods are affected and varied. For this reason the required torque will also be affected. He reviewed some of the factors affecting the selection and operation of cultivation implement as given below.

1 - type of soil.
2 - kind of crop.
3 - moisture content.

With regard to soil pulverization Hendrick and Gill(3) pointed out that one of the main objectives of rotary tiller is to break the soil into finer size particles. They also concluded that soil pulverization increases with depth. This is because more blades will pass through the area and the probability of the soil being recirculated is increased. Billat (cited by Hendrick3) indicated that rotary speed appeared to have greater influence on clod size than did the depth of operation.

As for the geometry of cutting operation and power required, Hendrick and Gill(3) pointed out that the power requirement increases with the length of path of the blades. In an endeavour to obtain the minimum length of path, at which the power requirement will be minimum, they studied the relation between the drum radius and the depth of cut. They found that the optimum theoretical diameter-to-depth ratio at which the length of path-to-depth ratio is minimum ranges between 1.13 to 1.33. Söhne (Cited by Gill)4 investigated the influence of rotary speed on average torque. He reported that the average torque increases linearly with rotary speed. Moreover, Adams and Furlong(5) studied the effect of rotary speed and drum radius on horsepower. They found that the required power increases with the rotary speed and drum radius. In other words, the power requirement increases with the drum peripheral speed.

3 - <u>EQUIPMENT:</u>

3-1 <u>Rotary Cultivator:</u>

A (MAB) rotary cultivator was used as a power-driven rotary cultivator to be tested in this work. It is composed of a 14 hp motor and a power-driven 40 cm diameter drum to which the cutting blades are attached as shown in Fig. (1). The blades are arranged in 4 courses equally spaced on each side of the machine. Each course contains 4 blades at equal angular spacing viz. 90°. The entire drum width amounts to 105 cm.

To control the depth of cut, a depth regulator time is attached at the rear of the machine as shown in Fig. (1). It controls the depth of cut through its sinkage in the soil. The operator holds and controls the machine by using the handle-bar.

3-2 Instrumentation:

A torque transducer was used to measure the drum torque. It was mounted on the right hand side part of the drum as viewed from the rear as shown in Fig. (2). The signal coming from the transducer was received by a carrier-frequency measuring bridge. It was used as a conditioning unit for measuring the torque. The output signal from the conditioning unit was transmitted to achart recorder. Recording was carried out with a pen on a roll of graph paper. However, the schematic block diagram of the measuring apparatus is as shown in Fig. (3).

The rotary speed was measured by using a Multi-Tachometer. The experimental work was carried out in the Faculty of Engineering and Technology in Shebin EL-Kom.

4 - EXPERIMENTAL PROCEDURE:

Four courses of blades were mounted beside the torque transducer as shown in Fig. (2). The bridge readings and chart recorder values were then calibrated.

4-1 Torque Measurement:

The transducer was connected to the conditioning and recording units through a sufficiently long cable to allow for machine test strokes. The maximum and minimum values of torque were taken from bridge readings. The average value of torque was determined from the chart recorder.

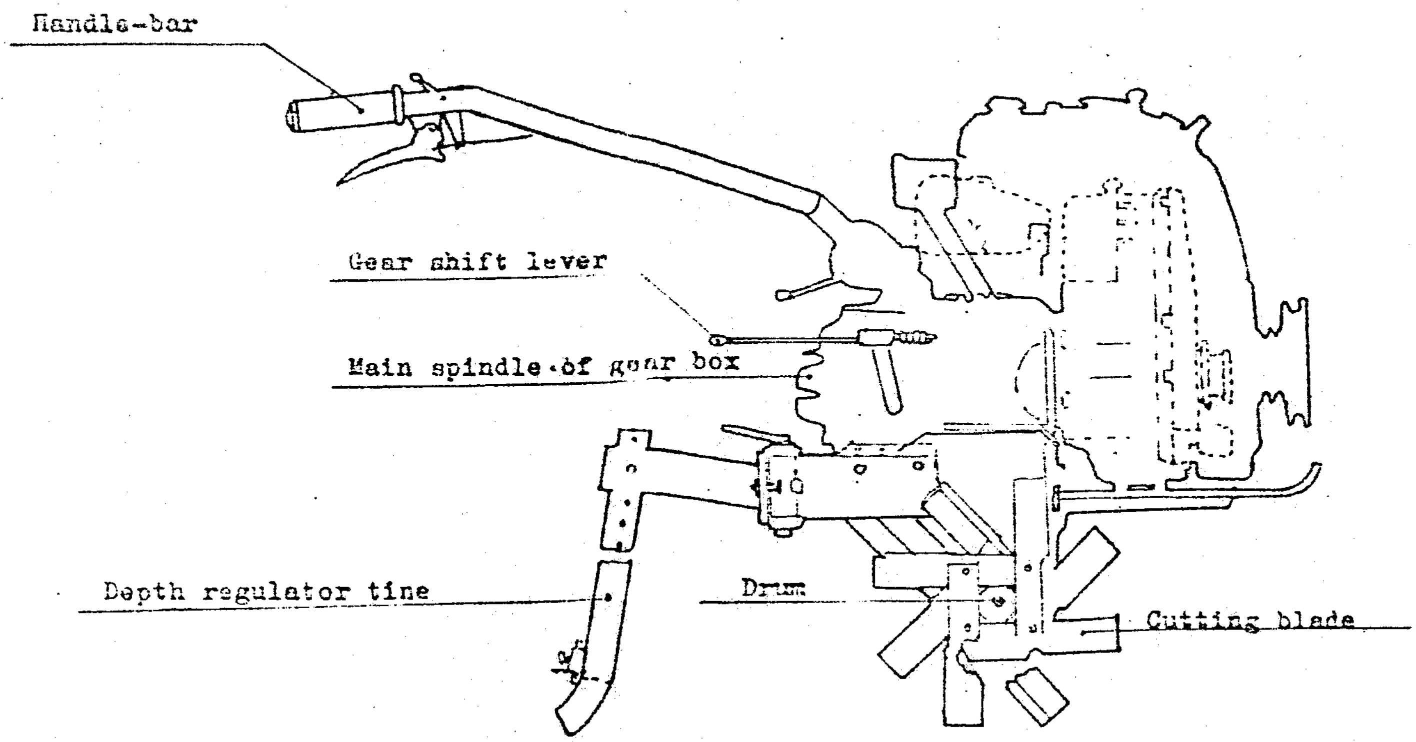


Fig. (1) The self-propelled rotary cultivator

4-2 Depth and Speed Measurements:

Depth measurements were carried out on both sides of the drum at regular intervals of 2 metres. The engine rotary speed the measured with the tachometer. The forward speed was measured by using a stop watch.

5 - RESULTS AND DISCUSSION:

5-1 Theoretical Approach:

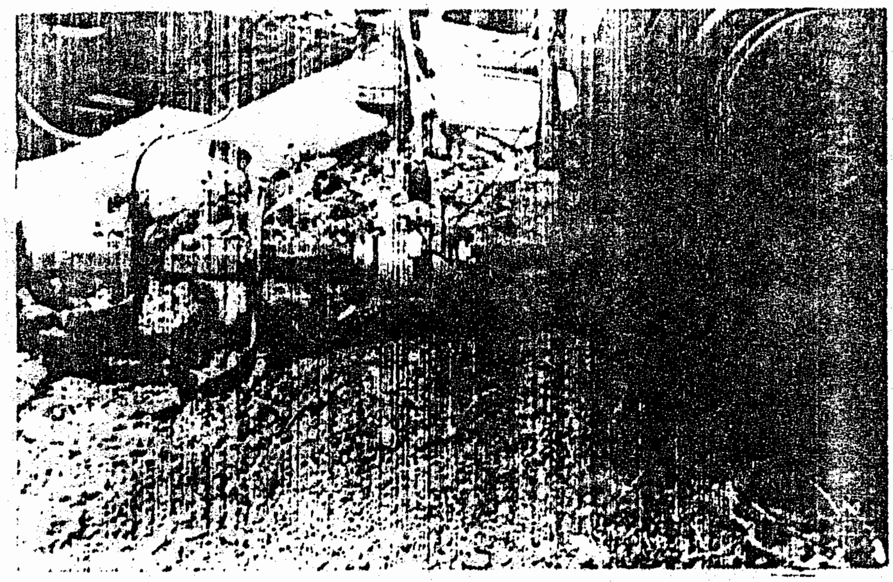
The performance of the rotary tiller under consideration depends to great extent on the operator. A better understanding of the tillage operation as carried out by the rotary tiller, is therefore very helpful in achieving a better performance and effeciency of tillage operation. The machine works by virtue of the drum rotation. The operator holds the handle-bar of the machine and lets the drum rotate by means of the clutch. As the drum rotates it starts to penetrate deeper into the soil under the effect of vertically downward force acting on the drum. By virtue of the cutting process carried out by the blades of the drum rotation the machine goes forward at particular forward speed V. During the advance of the machine the soil is cut, pulverized and thrown backwards by the blades of the drum.

Throughout the advance of the machine with the drum rotation each blade on each course on the drum cuts a new slice of the soil. The width of soil slice in direction of travel, called width of bite and denoted by B, is as given by equation(2-1).

With regard to the force acting on the machine, these forces may be sorted out as shown in Fig. (4) as follows:

W = machine own weight acting at C.G,

R_d= soil reaction on drum, this force may be measured to be acting tangentially on drum circumferance at a point d at the middle of the depth of cut at a vertical distance $\frac{Z}{2}$ as shown in Fig. (4).



A close-up of the torque transducer on the R.H.S. of the drum.

Fig. (2) The rotary cultivator used in the experimental work.

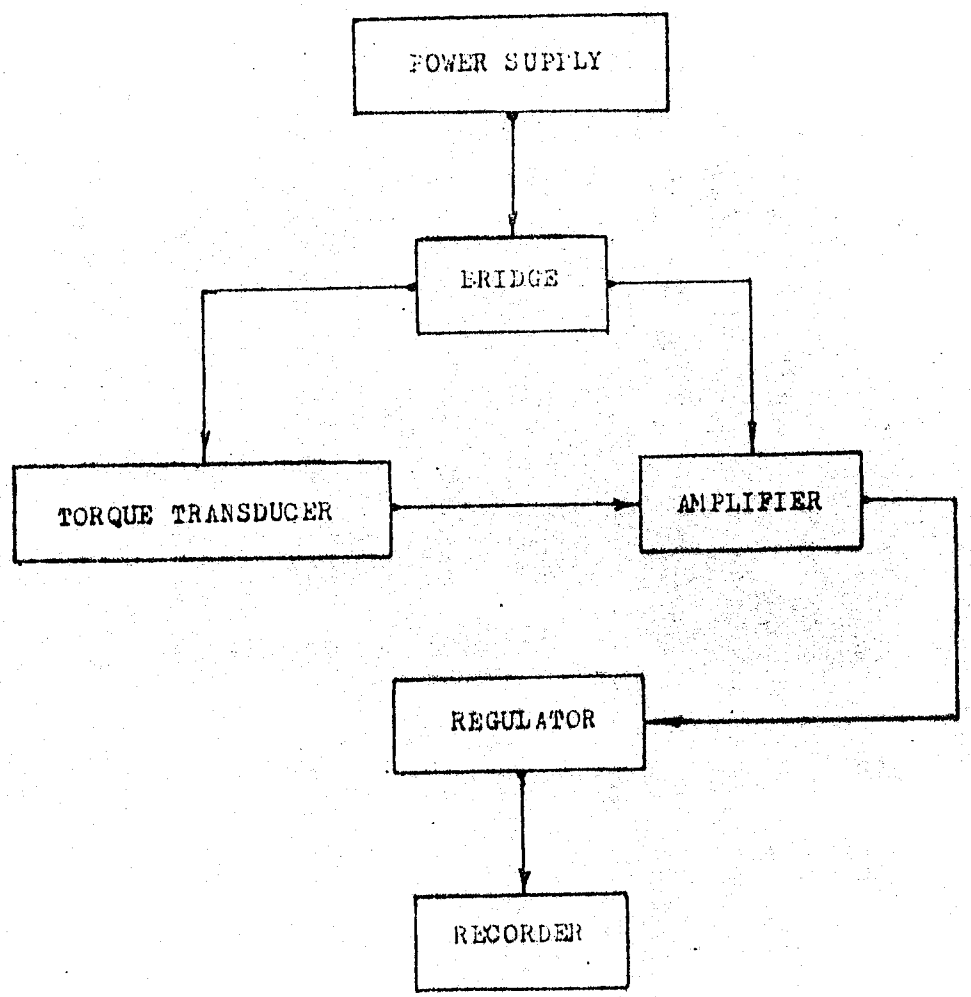


Fig. (3) A schematic block diagram of torque measuring apparatus.

H_c and V_c = Soil horizontal and vertical reactions on depth regulator tine respectively,

H_p , V_p = Operator reactions on handle-bar,

W_d = Any added dead weights on the handle-bar. This force acts vertically downwards.

Considering the horizontal components acting on the machine,

$$H_d = H_c + H_p \qquad \text{..............(5-1)}$$

$$V_c+V_d = W + W_d + V_p \qquad \text{..............(5-2)}$$

In which V_d = Vertical component of soil reaction on the drum.

Since the drum is the most important part of the machine, some further study of the forces acting on this part, may be of good use in investigating the tillage operation as carried out by the drum. Consider a free body diagram of the drum as shown in Fig. (5).

J = The drum weight plus the vertical reaction of the machine at the drum centre,

Q = Horizontal component of the resultant reaction of the machine,

= Angular speed of drum,

= Speed ratio.

Hence, $T = T_s + T_c$ ....(5-3)

where T_c = The torque needed for cutting and pulverizing the soil which is such that,

$T_c = R_d . R$

The ratio between these two types of torque depends to great extent upon the soil type.

5-2 Depth of Cut:

Depth of cut can be changed by the depth regulator tine. Increasing the depth of the depth-regulator tine leads to increasing H_c and, consequently, H_d as indicated by equation (5-1).

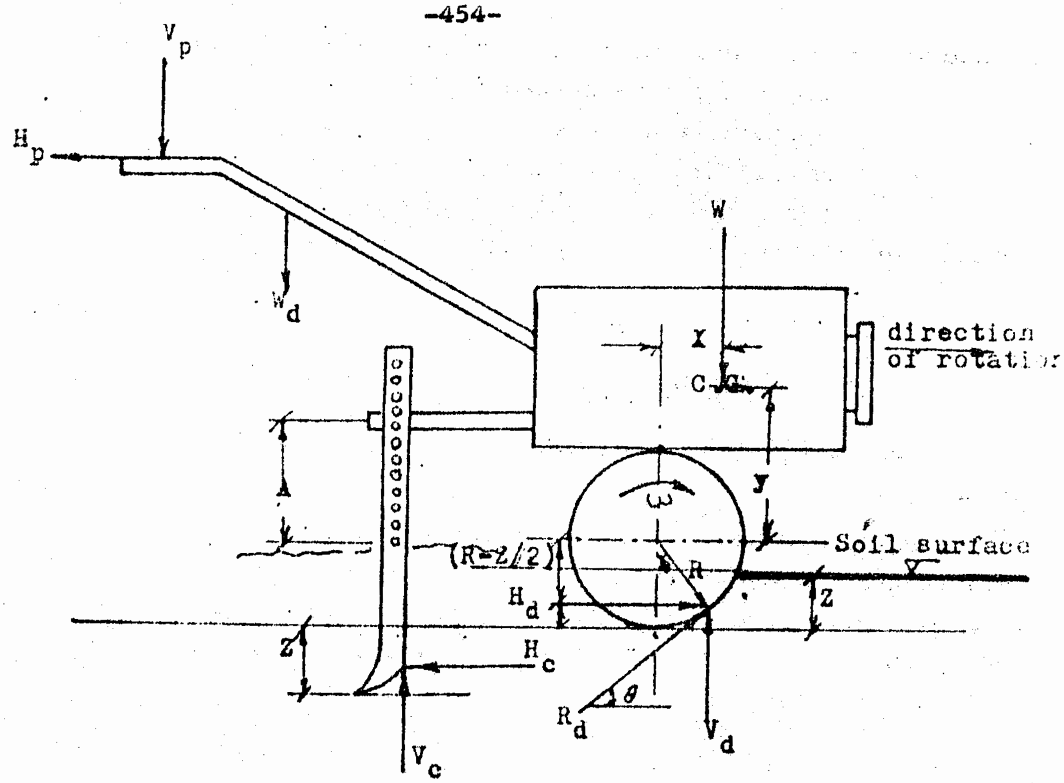


Fig. (4) Vertical force relations for the rotary cultivator in the vertical plane parallel to the direction of travell.

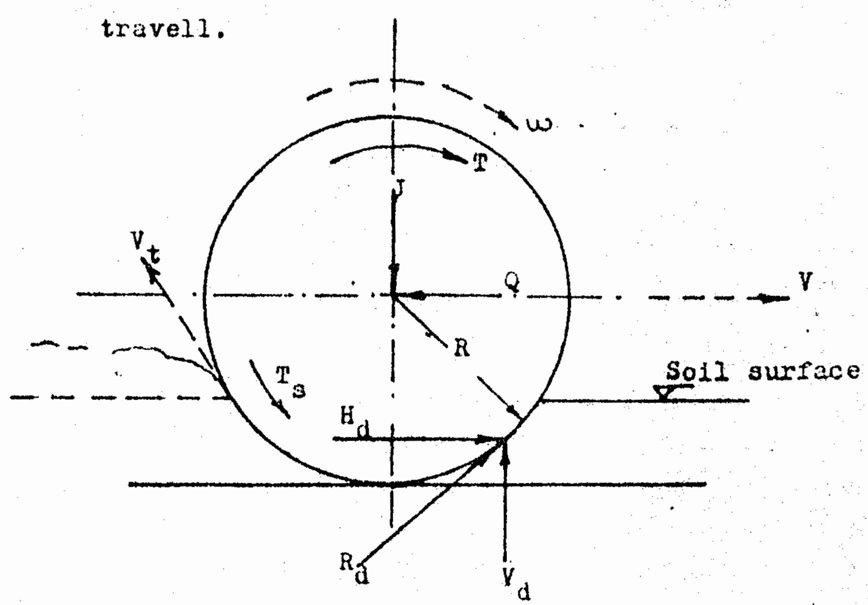


Fig. (5) A free body diagram of the drum.

Assuming that the ratio V_d/H_d is constant V_d will increase as a result, i.e, increasing the depth of cut.

The relationship between the relative position A of the tine, and the average depth of cut is as shown in Fig. (6). The relation between A and $\bar{Z}$ has been statistically found to be as given in equation (5-4) below.

$$\bar{z} = 0.96 \ A - 0.95 \qquad \text{..............(5-4)}$$

$$r = 0.99$$

The relation between A and $\bar{Z}$ indicates that the average depth $\bar{Z}$ increases linearly with the depth of the regulator tine.

5-3 Power Requirements:

The power transmitted from the engine is generally expended on three types of power requirement as classified below.

P_1 = Power for cutting and pulverizing the soil.
P_2 = Power required for driving the machine forwards.
P_3 = Power for throwing the cut soil backwards.

Then the total power required from the engine is as given in equation (5-5) below:

$$P = P_1 + P_2 + P_3 \qquad \text{..............(5-5)}$$

The power P_1 depends on the soil strength which is, in turn, dependent on the soil type and conditions. It is the only useful power taken from the engine. P_1 is, in fact, the power needed to overcome the resisting torque T_c and it can thus be expressed as given in equation (5-6) below.

$$P_1 = T_c. \qquad \text{..............(5-6)}$$

With regard to the power P_2 required for driving the machine forwards it is as given in equation (5-7) as follows.

$$P_2 = V \ (H_c + H_p) \qquad \text{..............(5-7)}$$

It is, therefore, evident that P_2 increases with H_c which increases with depth of regulator tine. Then, increasing the depth of this tine leads to increasing the parastic power P_2. This power

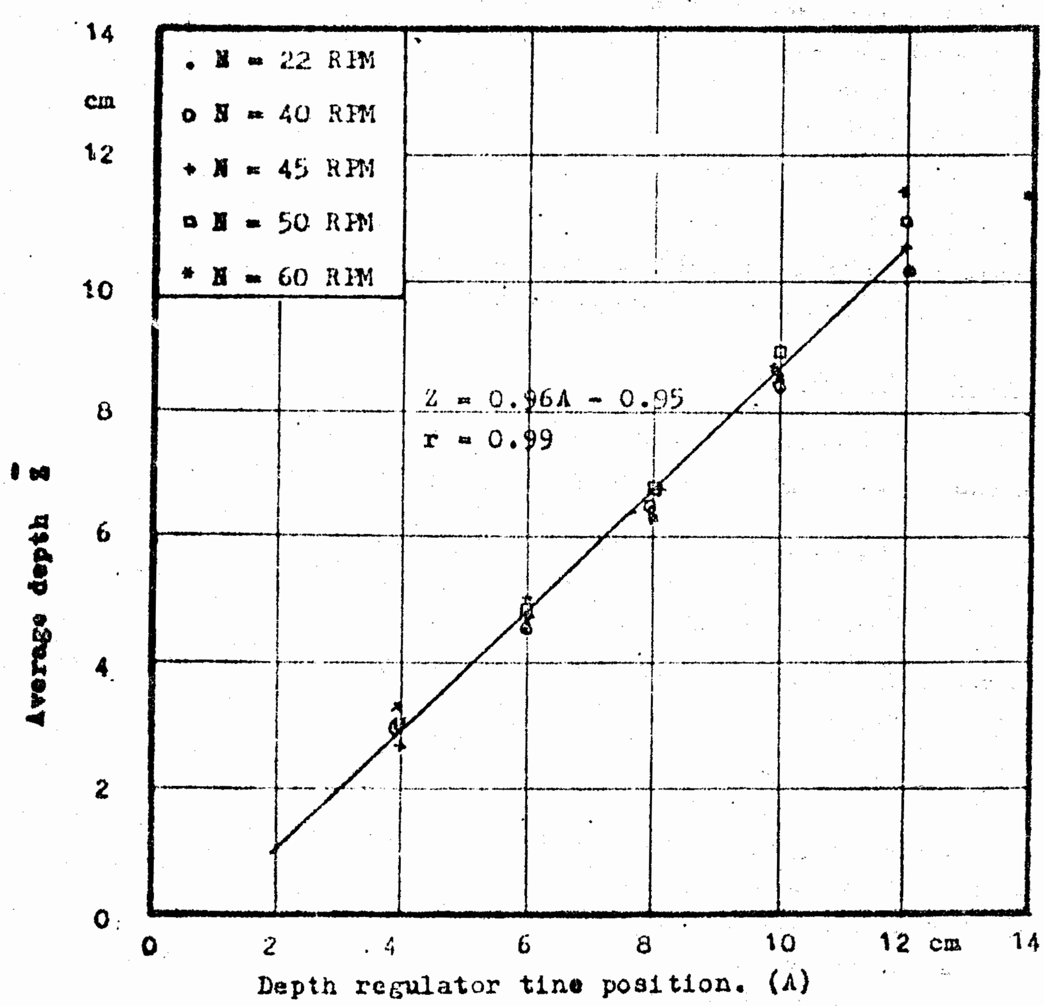


Fig. (6) The overall average of penetration vs. depth regulator tine position at various levels of drum rotary speed.

depends also on human factors as is evident by including H_p in equation (5-7).

As for P_3, it is the power required to overcome the torque T_s.

$$P_3 = T_s. \qquad \text{..............(5-8)}$$

5-4 <u>The Effect of Depth of Cut and Drum Rotary Speed on Rotational Power:</u>

The rotational power is the major part of the total power transmitted from the engine. It can be readily calculated at each rotary speed for various values of depth of cut. Fig. (7) shows the experimentally found relation between the depth of cut and power requirement at various levels of drum rotary speed. It is clear from this figure that the rotary power increases with both the depth of cut and the rotary speed of the drum. The power difference at a particular depth of cut is not proportional to the corresponding difference in rotary speed. It might be helpful to have some light thrown on this phenomenon. Increasing the drum speed results in an increase in the speed ratio. As a consequence, the tilling pitch or the width of bite B decreases according to equation (5-2). This leads to greater soil pulverization which entails greater energy[3], i.e, T_c increases with the drum rotary speed resulting in a greater rotary power requirement.

The specific energy per unit mass of tilled soil is computed versus depth at the same values of the drum rotary speed as shown in Fig. (8). It is indicated from Fig. (8) that the rate of change of the specific energy per unit mass of soil increases with the drum rotary speed.

6 - CONCLUSIONS :

The existing power-driven rotary cultivators have been found to be disadvantageous in some respects. Due to fatigue effect caused by vibrations and reactive forces resulting from land

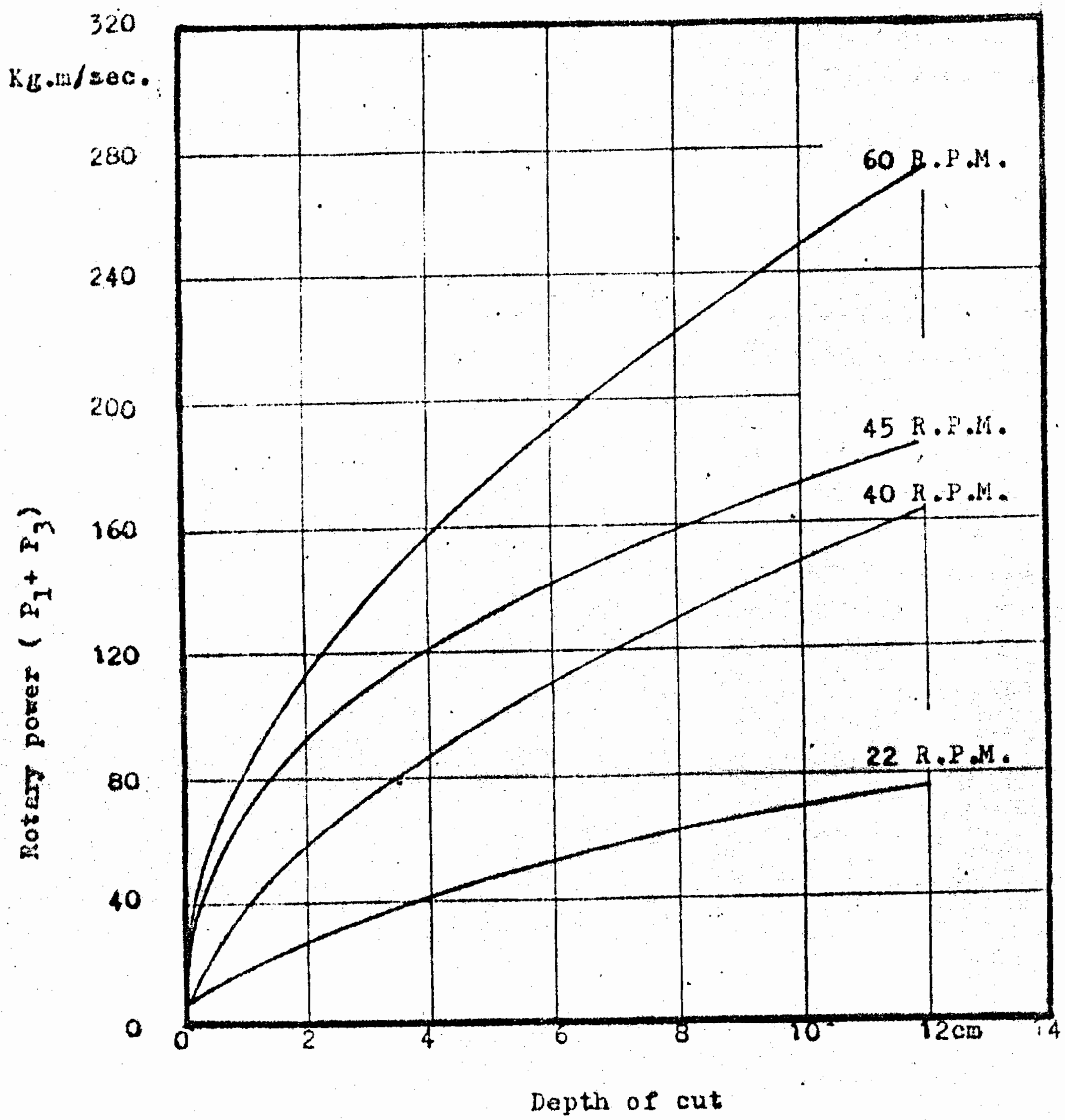


Fig. (7) Effect of depth of cut on the drum rotary power.

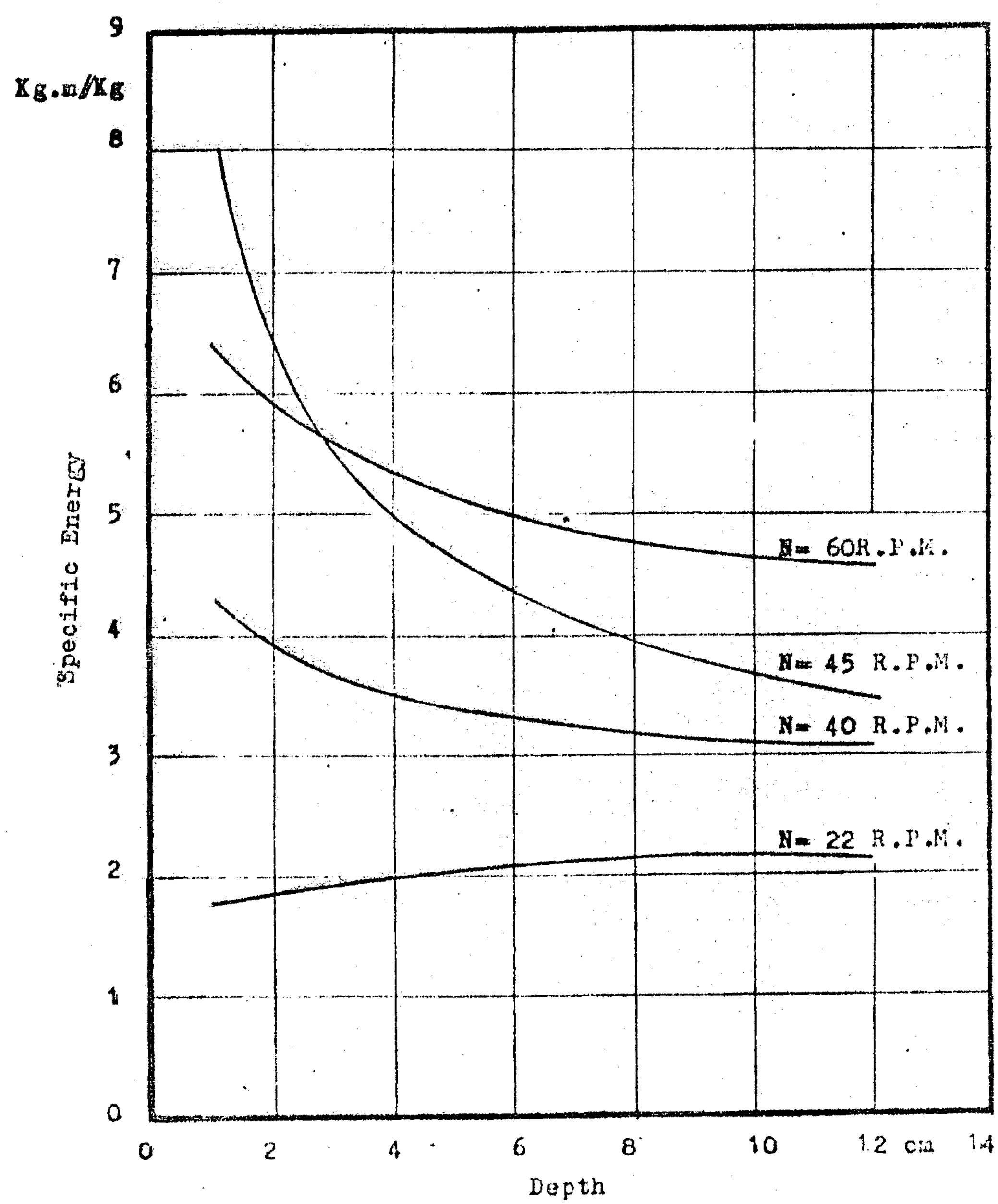


Fig. (8) The relation between depth of cut and specific energy per unit mass of soil.

undulations and sprocketive construction of cutting blades, it is necessary to replace the operator at short intervals.

However, the power and energy requirements, were experimentally and theoretically studied as affected by both the depth of cut and the drum rotary speed. The relevant empirical relationships between the depth of cut and drum rotary speed as independent variables and rotary power and specific energy as dependent variables have been statistically derived from the experimental date. The rotary power has been found to increase with both depth of cut and drum rotary speed. Whereas the specific energy per unit mass of soil has been found to decrease with depth of cut but it was higher at higher rotary speeds.

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الاختيار الهندسي والاقتصادى الأمثل للعزاقات التى تخدم حدائق المواليح

٢ ـ دراسة أداء العزاقات

١ ـ أ٠د٠ عبدالهادى عبدالبارى ناصر ٢ ـ أ٠د٠ عثمان الخولى
٣ ـ دكتور/ نبيل عبدالحميد أبوالعيس ٤ ـ م٠ فوقية رمضان جمعة

الملخص

نتيجة لاستعمال ماكينات العزيق بدلا من العمل اليدوى ٠ فان دراسة أداء الماكينة يعتبر من الموضوعات المهمة ٠

العوامل التى يتأثر بها أداء الماكينة هى :

١ ـ عمق القطع " العزيق " ٢ ـ السرعة الدورانية ٠

وتقوم الدراسة فى هذا البحث على بعض بارمترات الأداء مثل ـ القدرة المطلوبة والطاقة النوعية لكل وحدة كتلة من التربة ٠

ولوحظ أن القدرة المطلوبة تزيد بزيادة عمق القطع والسرعة على عكس الطاقة النوعية حيث تزيد السرعة وتقل عندما يزيد عمق القطع وبذلك يمكن اختيار القدرات المناسبة للقيام بعملية العزيق بما يتناسب مع ظروف العمل ٠