Misr J. Ag. Eng., 26(1): 56- 68 FARM MACHINERY AND POWER

EFFECT OF KINEMATIC PARAMETER ON SOME PERFORMANCE INDICES FOR THE SELF-PROPELLED COMPOST TURNING MACHINE

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ABSTRACT

Self-propelled compost turning machine performance in terms of machine capacity, compost density, fuel consumption, energy requirements and turning cost was investigated as a function of change in the kinematic parameter (ratio of drum peripheral velocity to machine forward speed) during the compost turning operation.

From the obtained data it can be concluded that:

- Machine capacity increased by decreasing the kinematic parameter.

- Compost density decreased by increasing the kinematic parameter .

-Energy requirements as well as turning cost were minimum at a kinematic parameter value of 35 .

INTRODUCTION

Mechanization of compost turning operation is considered of great importance to reduce time period to maturity, labor and cost. Different types of turning machines are in the view in compost fields nowadays. Among these machines is the self-propelled compost turning machine.

The major function of the compost turning operation is to mix compost materials, rebuild the porosity of the compost and releases trapped heat, water vapor and gasses. This exposes all materials equally to the air at the outer surface. The compost turning machine performs complex motions. For example, a translatory motion with the machine and relative motion due to the positive drive of the turning drum.

El shal M.s. and M. M. Morad (1991) stated that the combine header performance during the harvesting operation of a standing and lodging rice reveal the reel kinematic parameter of 1.2 and 1.5 for standing and lodging rice respectively are considered the optimum values for minimizing the header losses.

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Morad and El Shazly (1994) stated that the adjustment of rotary plow kinematic parameter improved tillage performance. They also showed that rotary plow kinematic parameter of 2-2 minimized energy requirements and improved tillage efficiency.

Morad (1995) stated that the proper adjustment of kinematic parameter for the rotary mower during the mowing operation is of great importance to increase crop yield and decrease cost requirements. Decreasing the rotary mower kinematic parameter lead to increase field capacity and cutting height, while decreased field efficiency, cutting efficiency, fuel consumption and energy requirements. Rotary mower kinematic parameter value of 25 minimized the mowing cost

Mohamed et al. (1999) showed that the higher values of harvesting machine kinematic parameter are more effective in lifting lentil plants and lay them back on to the cutter bar. To avoid the shacking action of the mower cutter bar. Increasing kinematic parameter values from 1.33 to 2 increased grain losses from 5.9 to 8%. It was recommended to harvest lentil crop by using the self-propelled harvesting machine at a reel kinematic parameter of 1.33

Abd El-Mottaleb (2006) showed that the increasing machine forward speed from 200 to 600 m/h at various rotor speeds of 80, 160 and 240 rpm. Lead to increase fuel consumption by 14.9 to 19.1 and 26%, the power requirement by 14.9, 23.2 and 26.9%, and the energy requirements by 12.40, 21.50 and 28.10% respectively, when used the self propelled turning machine .

Alfano et.al (2007) planned and realized, Sixteen turning operations were executed, 12 during the first five weeks and 4 during the following 4 weeks of the process. In each turnover cycle, each pile was turned over twice and the complete operation took 30 min. Labour cost 30 Euro h^{-1}. Total cost of the turning operations was 285Euro. The cost of the complete composting process in the first year amounted to 4200 Euro, making the cost of our cured compost 0.63 Euro. kg^{-1}

Fouda et. al (2008) showed that by increasing compost turning machine forward speed from 1200 to 1500 m/h fuel consumption increased from 7.5 to 10.0 lit/h relating to the required power, data show that increasing machine forward speed from 1500 to 2000 m/h. increased the required power from 26.5 to 35 kW. at a constant turning number of four times per month and pile height of 100 cm when used the small scale local manufactured self propelled turning machine .

This work well cover theoretical and experimental analysis on the compost turning machine kinematic parameter (ratio of drum peripheral velocity to machine forward speed) to optimize its value for the purpose of improving some performance indices.

MATERIALS AND METHODS

Experiments were carried out at Ramsis company for management of Agr. Projects and Super Bio Company for Compost, Sharkia Governorate to optimize the kinematic parameter of self-propelled compost turning machine.

-The used raw material

Crop residues (especially rice straw) were used as a raw material for producing compost . Poultry and live-stock manure were also used to accelerate composting process. Added to that a finished compost was used as a supply of microorganisms.

- The used compost turning machine

The imported self-propelled compost turning machine was used as shown in Fig. 1 .Some machine specifications are shown in Table 1:

Table1:The self-propelled compost turning machine specifications.

Manufacture country	Model type	Engine type	Rotor diameter, mm	Rotor length, mm
Germany	Backhus 15 – 50	Diesel (112 kW)	1000	4350

-Kinematics of compost turning machine

The blades of turning drum perform complex motions. They perform translatory motion with velocity (v) and rotary motion of angular velocity (ω) around their axes (O). (Klenin et al., 1985).

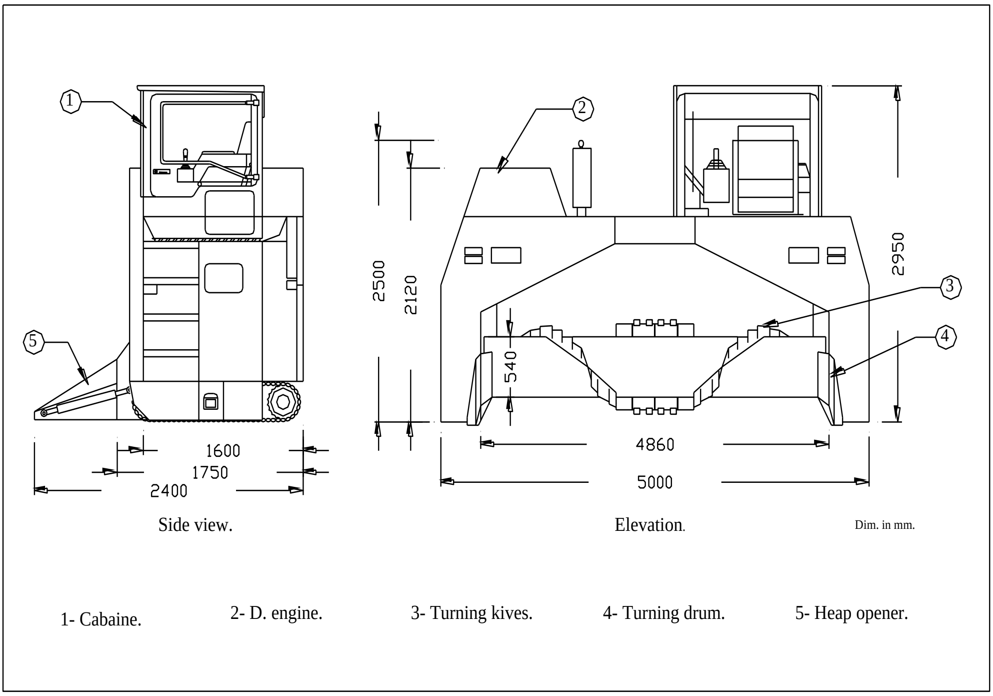

Fig. 1:Elevation and side view of the self-propelled compost turning machine

The blades of turning drum (fig.3) rotate in a plane coinciding with the direction of motion. The origin of the coordinate system coincides with the axis O of the shaft with the X axis along the direction of motion and the Y axis directed downward. The extreme point on the blade (A_o) is initially on the axis X. After an interval of time t, the axis of the shaft is displaced to the position O_1, having covered the distance (Vt) . During this interval, the blade turns through an angle (ω t) . The point A_o goes to position A, the coordinates of which are obtained as follows:

$$\dot{X}_A = Vt + R\cos\omega t$$

$$\dot{Y}_A = R\sin\omega t$$

Where: R distance from the axis of the shaft to the extreme end of the blade. By differentiating the above equations, horizontal and vertical components of speed can be determined.

$$\dot{X}_A = V - \omega R\sin\omega t$$

$$\dot{Y}_A = \omega R\cos\omega t$$

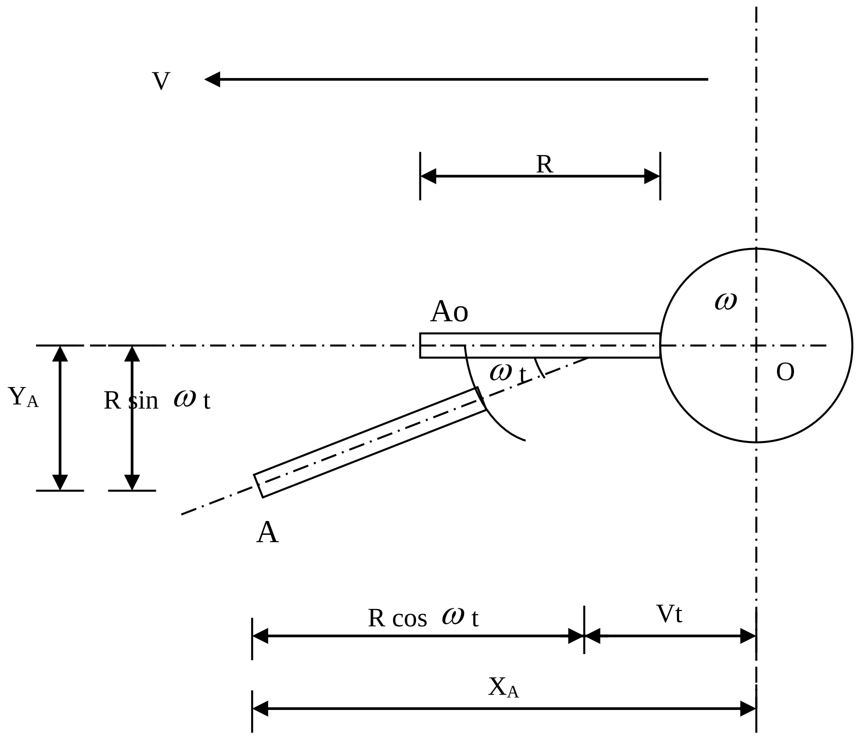

Fig.2 : Kinematics of compost turning machine

The blades get into contact with the composting windrow at a rotation angle of ω t. In this position, the blades motion is preferred to be only in the vertical direction and as a result, the horizontal component of the blades should equal zero.

$$\dot{X}_A = v - \omega R \sin \omega t_1 = 0$$

$$\text{Or} \quad \sin \omega t_1 = \frac{v}{\omega R} = \frac{1}{\lambda}$$

Where λ - the kinematic parameter of the turning machine (ratio of rotor peripheral velocity to machine forward speed, Since sin $wt_1 \leq 1$, so $\lambda \geq 1$. This means that the blade peripheral speed should be equal to or higher than the machine forward speed.

$$\lambda \geq \frac{\omega R}{v}$$

The turning pitch (S_H), according to the definition put forward by kepner *et.al*.,(1972), is the amount of travel per revolution

Hence, turning pitch = time per revolution X forward speed i . e. $$S_H = \frac{2\pi}{\omega}.v$$

$$S_H = \frac{2\pi R}{\lambda}$$

Assuming that the number of blades per course n,

So $$S_z = \frac{2\pi R}{n\lambda}$$

Where S_z -turning pitch per blade

According to this analysis, the theoretical kinematic parameter can be estimated as follows :

$$\lambda \geq \frac{2\pi R}{s_Z n}$$

The previous equation shows that the kinematic parameter as well as the turning pitch have a great effect on the compost turning machine performance. So optimizing their values is considered of great importance for turning machine to decrease energy requirements and increase turning quality.

For the turning machine under test, according to the previous equation, the theoretical kinematic parameter can be estimated to be $\lambda \geq 31$ taking into consideration that s_Z = 10 cm

There are three ways in which the kinematic parameter can be varied: change the rotor radius, change the peripheral velocity and change machine forward speed.

So, in the present investigation, combination of the above mentioned factors were taken into consideration to obtain different kinematic parameters for selecting the optimum value experimentally.

The experiment was conducted under conditions of constant rotor peripheral velocity of 240 rpm and five different forward speeds (2000, 2200, 2500, 3000 and 3500 m/h)which corresponded to five different kinematic parameters value of 25, 30, 35, 40 and 45.

Evaluation of the above mentioned kinematic parameters was done taking into consideration machine capacity, fuel, power, energy and turning cost.

Measurements

Compost density (ρ)

Compost density was determined according to the following formula :

$$\rho = \frac{m}{v}$$

where ρ - compost density ,k g / m^3 ; m – compost sample mass , kg

v – compost sample volume , m^3 .

Machine capacity (M. C)

Machine capacity (m^3 / h) was determined using the following equation :

$$M . C = A \times V$$

Where A – operational cross sectional area, m^3

V – machine forward speed , m / h .

Fuel consumption (F. C)

Fuel consumption was recorded by accurately measuring the decrease in fuel level in the fuel tank immediately after excuting each operation.

Turning power (T. P)

The turning power was calculated by using the following formula (Barger et. al., 1963).

$$T.P = F.c \times C.v \times \eta_{th} . \times 427 \times \frac{1}{75} \times \frac{1}{1.36} kW$$

where F. c - Fuel consumption , kg/s ;

C.v – Calorific value of fuel , k cal / kg (C. v = 10000 k cal / kg)

427 – Thermo mechanical equivaleut , kg.m / k cal;

η_{th} - Thermal efficiency of the engine , % (η_{th} = 30% for diesel engine)

Energy requirements (E.R)

Energy requirement can be calculated by using the following equation :

$$\mathrm{E.R(W.h/Mg)} = \frac{\mathrm{T.P(W)}}{\mathrm{M.C(m^3/h)} \times \rho\left(\mathrm{Mg/m^3}\right)} \times \mathrm{turning.nu\ mber.to.moturity}$$

Turning cost (T.C)

Machine cost was determined using the following formula (Awady 1978)

$$c = \frac{p}{h}\left(\frac{1}{e} + \frac{i}{2} + t + r\right) + \left(0.9hp \times f \times s\right) + \frac{w}{144}$$

where c- hourly cost. p- capital investment h- yearly operating hours e- life expectancy i- Interest rate t- Taxes and over heads ratio r- Repairs ratio of the total investment hp- Horse power of engine. f- Specific fuel consumption, lit/hp-h s- Price of fuel per liter w- Labor wage rate per month in L.E. 144- Reasonable estimation of monthly working hours.

Turning cost can be determined using the following equations :

$$\text{Operational cost (L. E. / m3)} = \frac{\text{Machine cost (L. E. / h)}}{\text{Machine capacity (m3 / h)}}$$

$$\text{T.C(LE / Mg)} = \frac{\text{Operationl cost}}{\text{Composting density (Mg/m3)}} \times \text{turning.number.to.moturity}$$

RESULTS AND DISCUSSION

The discussion covers the obtained results under the following heading:

- Effect of kinematic parameter on machine productivity:

The most critical factor in productivity of turning machine is kinematic parameter Fig. 3 shows effect of kinematic parameter value on machine productivity. Results show that by increasing kinematic parameter value from 25 to 45 machine productivity decreased from 2100 to 1600, from 2750 to 2100, from 3500 to 2550 and from 3800 to 3200 m^3/h under different pile heights of 60, 80, 100 and 120 cm respectively. The increase in machine capacity by decreasing kinematic parameter is attributed to the increase in quantity of turning materials per unit time because the decease in kinematic parameter is acquainted by an increase in forward speed.

-Effect of kinematic parameter on compost density:

Results show that compost density are inversely affected by the kinematic parameter Results in Fig. 4 show that by increasing

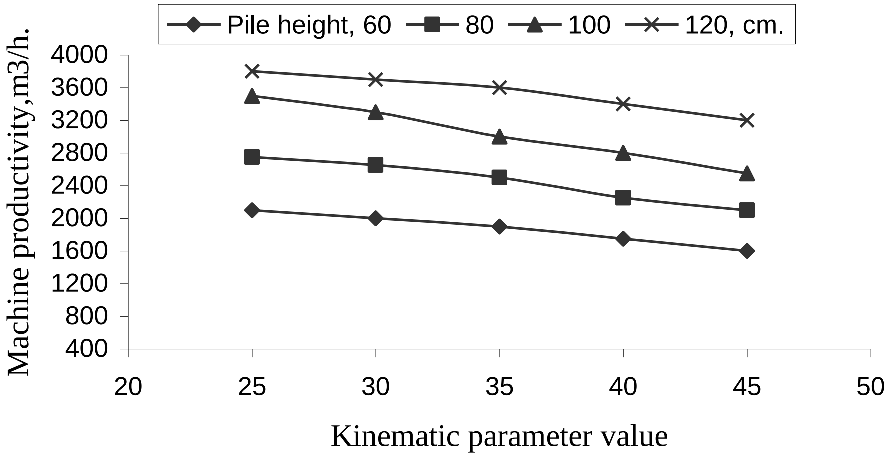

Fig. 3: Effect of kinematic parameter value on machine capacity at different pile heights.

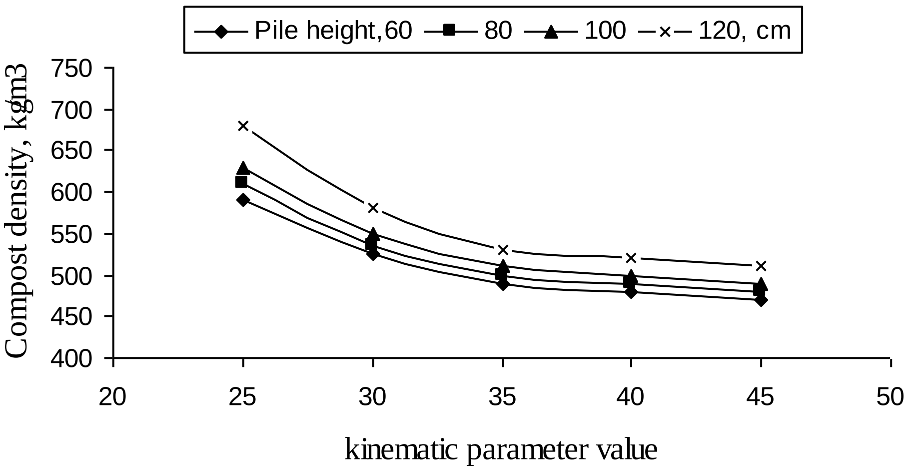

Fig. 4: Effect of kinematic parameter value on composting density at different pile heights.

kinematic parameter value from 25 to 45 compost density decreased from 590 to 480,from 610 to 490 , from 630 to 500 and from 680 to 520 kg/m^3 under different pile heights of 60, 80, 100 and 120 cm respectively. The decrease in compost density be kinematic parameter is attributed to more cutting and mixing by the rotor blades per unit volume of the disturbed compos due the high rotor velocity comparing with the low forward speed. This action increased the material volume resulting in a decrease in compost density.

- Effect of kinematic parameter on energy requirements

Results show that fuel consumption, required power and energy requirements are greatly affected by turning machine and kinematic parameter Fig. 5 Concerning the fuel consumption, the obtained data show that increasing kinematic parameter value from 25 to 45 pile height of 100 cm. decreased fuel consumption from 36.6 to 26.6 lit/h. As to the energy requirements, results show that increasing kinematic parameter decreased energy requirements up to 35 any further kinematic parameter increase up to 45, energy requirements will significantly increase. When the kinematic parameter was 35, energy requirements values was 875 W.h/Mg. under the same previous condition.

The increase in energy requirements by increasing kinematic parameter value from 35 to 45 is attributed to the increase in rotor blades knocking number per unit time on compost material. While the increase in the energy by decreasing kinematic parameter from 35 to 25 is attributed to the excessive load of compost material on the rotor blades added to the high impact of rotor with the compost material.

- Effect of kinematic parameter on turning cost

The most critical factor in selecting compost turning machine is the cost required for the turning operation. Results in Fig. 6 show the effect of turning machine as well as its kinematic parameter value on both hourly and turning costs. Data obtained show that increasing kinematic parameter value from 25 to 35 at pile height of 100 cm decreased turning cost from 15.3 to 12.7 L.E/ Mg. Any further increase in kinematic parameter from 35 up to 45, turning cost will increase from 12.7 to 14.9 L.E/ Mg under the same previous condition. (1$=5.45 LE)

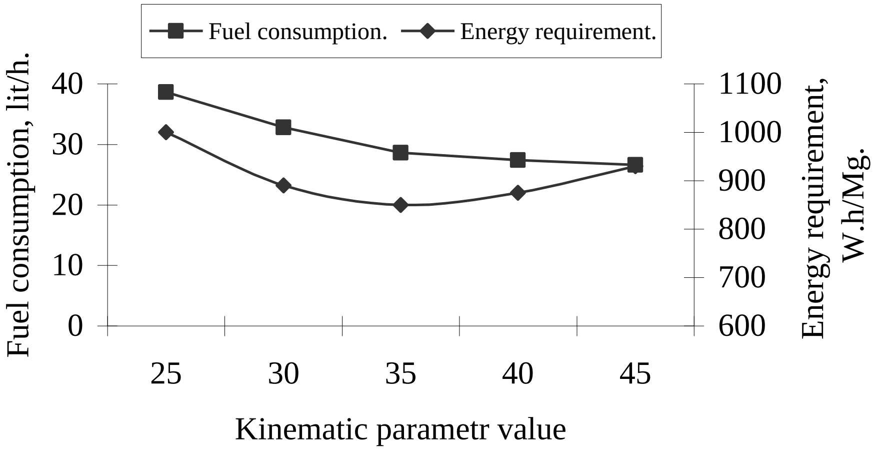

Fig. 5: Effect of kinematic parameter value on fuel and energy requirements at different pile heights

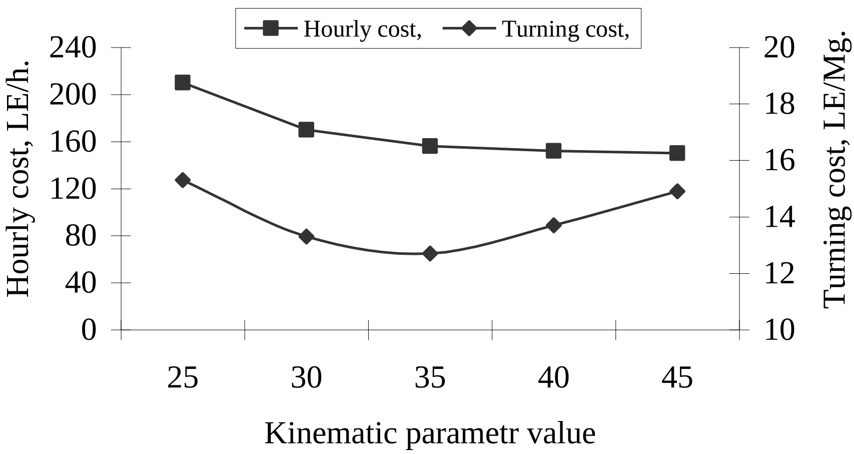

Fig. 6: Effect of kinematic parameter value on hourly and turning cost at different pile heights.

CONCLUSION

- The proper adjustment of turning machine kinematic parameter value during the compost turning operation is of great importance factor to decrease both energy and cost.

- Kinematic parameter range of 30 to 35 and pile height of 100 cm are considered the optimum conditions for compost turning operation.

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الملخص العربي

تأثير المعامل الكينماتيكى على بعض مؤشرات الأداء لآلة تقليب الكمبوست ذاتية الحركة

***طارق فودة**

يعتبر المعامل الكينماتيكى (نسبة السرعة الدورانية للدرفيل والسرعة الأمامية للآلة) من أهم العوامل التي تؤثر على عملية تقليب الكمبوست و التي لها علاقة مباشرة بتقليل كل من الطاقة والتكاليف.

لقد تم تحديد المعامل الكينماتيكى حسابيا ووجد انه يجب إن يكون اكبر من ٣١

لقد تم دراسة المعامل الكينماتيكى على أربعة مستويات وهى٢٥, ٣٠, ٣٥, ٤٠ و ٤٥ وارتفاع الكومة السمادية على أربعة مستويات وهى ٦٠, ١٠٠,٨٠ و١٢٠ سم وقد أسفرت النتائج عما يلي :-

تقل كثافة السماد الناتج بزيادة المعامل الكينماتيكى.

- تقل إنتاجية الآلة بتزايد المعامل الكينماتيكى

-يقل كل من الوقود والطاقة المستهلكة وتكاليف التقليب إلى أدنى الحدود عندما يكون المعامل الكينماتيكى في حدود٣٥ وعند ارتفاع كومة عند ١٠٠سم للكومة السمادية

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