1. Assanee AMNUAY[1], 2. Sonthaya GAWSOMBAT[1], 3. Parinya TOOMMALA[2], 4. Saktanong WONGCHAROEN[3*]

Electrical Technology Faculty of Industrial Technology, Ubon Ratchathani Rajabhat University (1)
Civil Technology Faculty of Industrial Technology, Ubon Ratchathani Rajabhat University (2)
Electronics Technology Faculty of Industrial Technology, Ubon Ratchathani Rajabhat University (3)
ORCID: 1. 0009-0008-3087-9710; 2. 0009-0000-8069-6113; 3. 0009-0006-7148-4251; 4. 0000-0001-6098-7204

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Development of a prototype Earthworm Waste Manure Sorting Machine Effective in 3 Steps

Abstract *This research proposed the development of an effective prototype for an earthworm manure sorting machine in three steps. Traditional earthworm waste manure sorting results in earthworm manure mixed with earthworm eggs or earthworms with draff. Moreover, a traditional machine cannot sort out the earthworm eggs to cultivate for breeding. The developed prototype earthworm waste manure sorting machine consisted of three steps for sorting: Earthworm Manure Fertilizer (EMF)), Coarse Manure with Egg (CME), and Draff and Earthworm (DE). A screen smaller than ∅2 mm was used in Step 1 to sort the EMF. A screen smaller than ∅3 mm was used in Step 2 to sort the CME, while a truncated cylinder material with a ½ Hp AC motor using a 230V, 50Hz power system driven with a gear speed reducer and belt at 48 rpm was used in Step 3 to sort the DE. The separation efficiency was tested by adjusting the angle of inclination to 10°, 20°, 30°, and 40°, respectively. The test results demonstrated that the most appropriate angle of inclination for the earthworm waste manure sorting machine that gave the highest efficiency was 40°. The efficiency values for EMF, CME, and DE sorting were 64.4%, 11.6%, and 23.2%, respectively. As for time efficiency, it took 2.2 minutes, which was the best time. The efficiency of energy use was 841.7W. The development of an effective prototype for an earthworm waste manure sorting machine in three steps had an efficient rate of earthworm manure sorting by setting the angle of inclination of the screen to 40°, which used less energy and needed the shortest sorting time. It reduced the steps for earthworm waste manure sorting, saved time and labour costs, and upgraded the well-being of the agriculturists.*

Streszczenie *W ramach tych badań zaproponowano opracowanie skutecznego prototypu maszyny do sortowania obornika dżdżownicowego w trzech krokach. Tradycyjne sortowanie odchodów dżdżownic prowadzi do wymieszania odchodów dżdżownic z jajami dżdżownic lub dżdżownic z wyschniętym parą wodną. Co więcej, tradycyjna maszyna nie jest w stanie sortować jaj dżdżownic w celu hodowli. Opracowana prototypowa maszyna do sortowania obornika od dżdżownic składała się z trzech etapów sortowania: nawóz z obornika dżdżownicowego (EMF)), gruboziarnisty obornik z jajami (CME) oraz dżdżownica i dżdżownica (DE). W kroku 1 do sortowania pola elektromagnetycznego użyto ekranu mniejszego niż ∅2 mm. W kroku 2 do sortowania CME użyto sita mniejszego niż ∅3 mm, podczas gdy w kroku wykorzystano ścięty cylinder z silnikiem prądu przemiennego o mocy ½ KM, wykorzystującym system zasilania 230 V, 50 Hz, napędzany reduktorem prędkości i paskiem przy 48 obr./min. 3, aby posortować DE. Skuteczność separacji sprawdzono, ustawiając kąt nachylenia odpowiednio na 10°, 20°, 30° i 40°. Wyniki badań wykazały, że najodpowiedniejszym kątem nachylenia sortownika odchodów dżdżownicowych dającym najwyższą wydajność był kąt 40°. Wartości wydajności dla sortowania EMF, CME i DE wyniosły odpowiednio 64,4%, 11,6% i 23,2%. Jeśli chodzi o efektywność czasową, zajęło to 2,2 minuty, co było najlepszym czasem. Efektywność zużycia energii wyniosła 841,7W. Opracowanie efektywnego prototypu maszyny do sortowania odchodów dżdżownicowych w trzech krokach miało efektywne tempo sortowania odchodów dżdżownic poprzez ustawienie kąta nachylenia sita na 40°, co wymagało mniejszego zużycia energii i najkrótszego czasu sortowania. Zmniejszyło liczbę etapów sortowania odchodów od dżdżownic, zaoszczędziło czas i koszty pracy oraz poprawiło samopoczucie rolników.* (***Opracowanie prototypu skutecznej maszyny do sortowania odchodów dżdżownic w 3 krokach***)

Keywords: Earthworm Waste sorting machine, Earthworm manure fertilizer, Coarse manure with egg, draff and earthworms
Słowa kluczowe: Maszyna do sortowania odpadów z dżdżownic, Nawóz z obornika z dżdżownic, Gruby obornik z jajkiem, zanurzeniem i dżdżownicami

Introduction

The sufficiency economy is the Royal inspiration by King Rama IX guiding the moderation concept for people to practice based on the idea of growing organic vegetables to eat and eating home-grown plants, which has been very successful. In addition, the waste from organic vegetables can be food for earthworms, which gives earthworm manure full of nutrients that are good for plants as a consequence. Earthworm manure contains various microorganisms that are beneficial and appropriate for plant growth as well as soil and environmental improvement [1]. However, earthworm manure from the culture is mixed with earthworm manure fertilizer, earthworm eggs, and draff. Thus, agriculturists must sort the components before selling the manure. Using a traditional sorting machine cannot sort out earthworm eggs and earthworms. For this reason, it is impossible to sort the earthworm eggs for culture and breeding. Moreover, sorting earthworm eggs requires labour [2], which adds more sorting steps, and wastes time as well as labour costs [3].

This research proposed a concept to invent an earthworm waste-manure sorting machine that is effective in three steps: Earthworm Manure Fertilizer (EMF), Coarse Manure with Egg (CME), and Draff and Earthworm (DE), to minimize the sorting steps, reduce the time and costs of labour, and upgrade the wellbeing of agriculturists.

Process of making earthworm manure

Earthworm manure is the decomposition process of organic substances [2, 4-5] eaten by earthworms via the activity of microorganisms in the intestines and enzymes before excretion. For this reason, earthworm casting is rich in certain nutrients that plants can use immediately. Further, earthworm casting contains numerous useful microorganisms that are suitable for the growth of plants, improving the environment and soil conditions. The process and steps of earthworm culture are as follows [6-7].

1) Prepare bedding - Cow dung is the feed and shelter for earthworms. Soak cow dung in the eater to release the heat and gas.

Fig. 1. Prepare bedding for earthworm food

2) Prepare earthworm feed - Put the feed into a container with a diameter of 50-55 cm containing a hole. Put 250 g of eggs and earthworms into the container filled with feed and shelter.

Fig. 2. Preparation of feed and shelter for earthworms

3) Put water to add moisture to the feed 1-2 times a week or 3-4 times in hot weather.

4) The period for earthworm culture is 30 days.

5) Earthworm waste manure sorting - Sort the earthworms from the manure using the traditional sorting machine, which will get the CME and DE.

Fig. 3. Traditional sorting of earthworm waste manure

Concept of earthworm waste manure sorting process

The concept of the earthworm waste manure sorting process can be classified into three steps [3, 7-9] as follows.

Step 1. Sort the EMF that is smaller than ∅2 mm.

Step 2. Sort the CME that is smaller than ∅3 mm.

Step 3. Sort the DE.

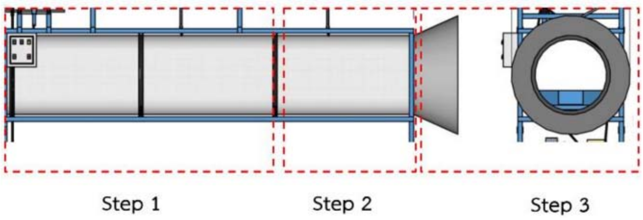

Fig. 4. Step for the machine to sort the earthworm manure

Fig. 4 displays the step for earthworm waste manure sorting through the sorting machine, which has three levels based on the size of the object. The first step sorts the EMF. The second step sorts the CME, while the last step sorts the DM.

Design and Invention of an Earthworm Waste Sorting Machine (EWSM)

1. Design of EWSM structure

The structure and components of the EWSM are as follows [10-15].

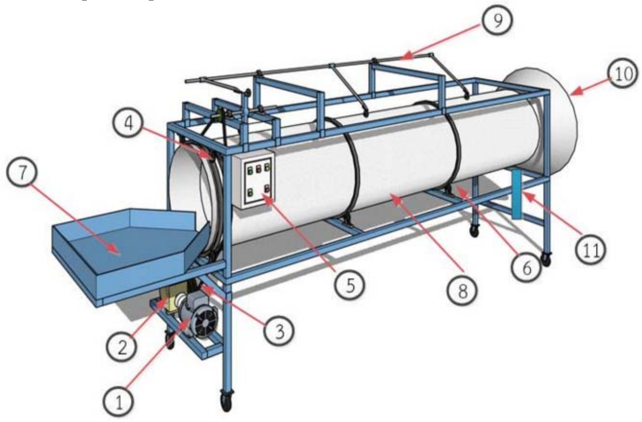

Fig. 5. Structure and components of the EWSM
1 - A motor; 2 - A worm gear reducer (WGR); 3 - V-belts; 4 - A bicycle wheel; 5 - A control system; 6 - Wheels for rolling screen
7 - A collected box; 8 - A rolling screen (Rs); 9 - An impact kit for rolling screen; 10 - A conical separator; 11 - A rolling screen level adjuster

2. Invention process for EWSM

The EWSM is a 2.7 m.-long horizontal cylinder with a diameter of 0.5 m. The height is 1.5 m., as shown in Fig.6.

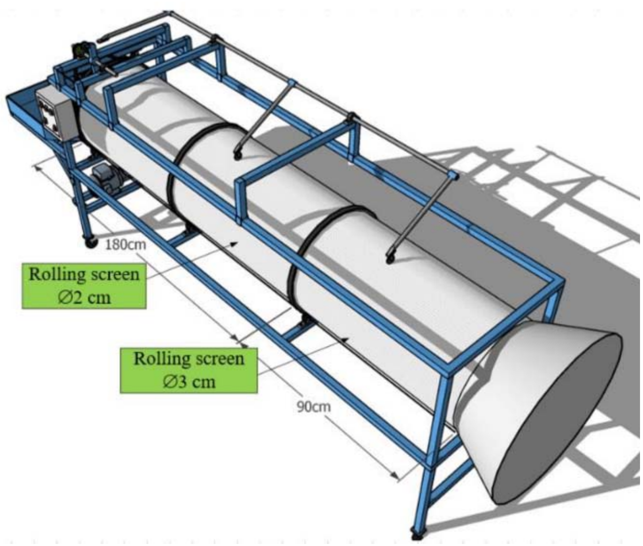

Fig. 6. Design of EWSM

The earthworm manure (EMS) consists of the mass, earthworm manure fertilizer (EMF), coarse manure with egg (CME), and draff and earthworm (DE), as in the formula.

$$\sum EWS = EMF + CME + DE \quad (1)$$

For separation efficiency, the sorting process consists of three steps.

2.1 Step for sorting earthworm manure fertilizer (EMF)

From Fig. 6, the EMF sorting uses the smallest set of the screen; the diameter of the hole is ∅2 mm and the length is 180 cm, which is the longest. It is the crucial part to sort the EMF. The percentage of EMF mass is calculated from the following formula.

(2) $$EMF = \frac{EMF_{(m)}}{EWS_{(mt)}} \times 100$$

2.2 Step for sorting of coarse manure with eggs (CME)

From Fig. 6, the CME sorting is the next step following the first screen. The diameter of the hole is ∅3 mm, and the length is 90 cm. This step sorts the coarse manure and eggs, which can be used in breeding to reduce costs, maximize yield, and generate income for the entrepreneur who is interested in earthworm culture. The draff and earthworm will be passed on to the final step. The percentage of CME mass is calculated from the following formula.

(3) $$CME = \frac{CME_{(m)}}{EWS_{(mt)}} \times 100$$

2.3 Step for sorting draff and earthworm (DE)

From Figure 6, a truncated cylinder is used in this step. When the draff and earthworm arrive at the sorting part, the draff, which is dried and does not attaché to the metal material, falls vertically due to gravity. Earthworms have a cuticle on the outer cell wall [9] coated with polysaccharides and gelatine as well as an epidermis that has glandular cells producing slime to coat and moisten the body, so them to attach to the metal material. When the cylinder inclines and rotates at different angles, the earthworms separate from the draff. The percentage of EMF mass is calculated from the following formula.

(4) $$DE = \frac{DE_{(m)}}{EWS_{(mt)}} \times 100$$

Fig. 7. Practical EWSM

Gear ratio and transmission calculation

To operate the EWSM with the electric motor, the appropriate speed for the highest efficiency is essential for energy savings by calculating the rotational speed or adjusting the rotational speed. The researcher designed, analysed, and carried out the test to acquire the highest efficiency by referring to the data from the manufacturer's instructions. The rotational speed of the motor is essential to design the EWSM. A ½ Hp, 4-pole induction motor is used with the power system in Thailand (230V, 50Hz) [16-19,] and was used in this research; it is available on the market and easy for maintenance. The synchronous speed was 1,500 rpm at 50Hz. [11-12]

The calculation for motor rotational speed uses the following formula.

(5) $$N_s = \frac{120F}{P}$$

where N_s = Synchronous speed (rms); F = Frequency (50Hz); P = Electromagnetic pole

In practice, the slip slows down the speed by 1-4%, so the rotational speed is 1,440 rpm. The M_L is as the following equation.

(6) $$M_L = \frac{(N_S - N)}{(N_S - N_{rated})} \times 100\%$$

whereL N_s = Synchronous speed; N = Measured synchronous speed ; N_{rated} = Rated load

Fig. 8. Motor efficiency test

After acquiring the rotational speed, the transmission system and gear ratio could be calculated.

1) Transmission system calculation

The calculation for torque of the transmission system in a 4-pole motor 0.35 kW [13] at a rotational speed of 1,440 rpm was 27.63Nm, per the following equation.

(7) $$T_m = \frac{\omega_m \times P}{N_m}$$

where: T_m = Torque of the transmission system (Nm); ω = Angular speed of the rated motor at 9,550 ; P = Electromagnetic pole; N_m = Rotational speed at 1,440 RPM

The calculation for the torque of the gear ratio for the worm gear and worm screw transmission system, which had the higher transmission than the other gear, was as the following equation.

(8) $$i = \frac{n_{wg}}{n_{ws}}$$

Where: i = Gear ratio; n_{wg} = Rotational speed of the worm gear (rpm); n_{ws} = Rotational speed of the worm screw) (rpm)

From equation (3), when the motor rotational speed was 1,440 RPM driven through the worm gear at a ratio of 1/10, the output rotational speed was 144 rpm. Thus, the torque increased to 276.3Nm.

2) Drive belt transmission system calculation

The calculation for the V-belt transmission system at a motor rotational speed of 1,440 rpm driven through the worm gear reducer (WGR) gave the rotational speed driven through the pulley (P). The output P_{n1} was 144 rpm where the size of the P_{d1} was 18 cm and Rs_{d2} was 54 cm. Thus, the rotational speed of Rs_{n2} was 48 rpm [3], per the following equation.

(9) $Rs_{n2} = \frac{P_{d1} \times P_{n1}}{Rs_{d2}}$

Where: Rs_{n2} = Rotational speed of the rolling screen (rpm); Rs_{d2} = Size of the rolling screen (cm); P_{d1} = Size of the pulley (cm); P_{n1} = Rotational speed of the pulley (cm)

EWSM efficiency testing

1) Set the machine by adjusting the inclination of the cylinder to 10°, 20°, 30°, and 40°, respectively.

2) Fill the cylinder with 5 kg of the earthworm manure for sorting to determine the efficiency of the EWSM.

Fig. 9. Preparation step for sorting 5 kg of earthworm manure

3) Step for EMF and CME sorting - The EMF was obtained after going through the first screen, which is the smallest screen with a diameter of 2 mm and the longest length of 180 cm. Then, the CME was obtained when it went through the second set of the screen, in which the diameter of the screen hole was 3 mm and the length was 90 cm. 4) Step for DE sorting - The cone material was used in this step. When the draff and earthworm arrived at this part, the draff fell into the container before the earthworm, which sorted the draff from the earthworm.

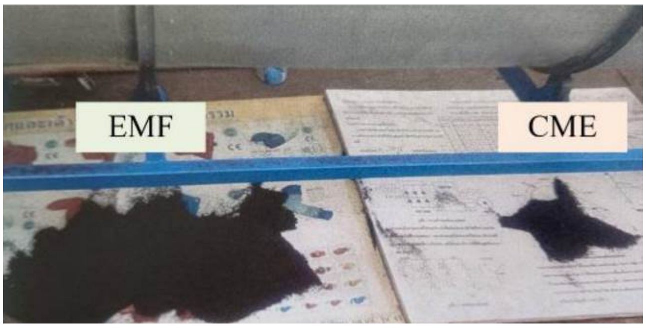

Fig. 10. Earthworm Manure Fertilizer (EMF) and Coarse Manure and Egg (CME)

Fig. 11. Draff and Earthworm (DE) sorting

Test results for separation efficiency

The EWSM efficiency testing at the static rotational speed of 48 rpm [3, 9, 14] was conducted five times by adjusting the inclination angle to 10°, 20°, 30°, and 40°, respectively, with 5 kg of earthworm manure each time. The average results are shown in Table 1.

Table 1. Average rate of EWSM sorting

Roller Screen Inclination (°)	Total mass of EWS (kg)	Earthworm separation rate								EWSM (Wh)
		Et (min)	EMF (kg)	CME (kg)	DE (kg)	E (kg)	EMF (%)	CME (%)	DE (%)	
10	5	10.38	3.42	0.48	0.98	0.12	68.4	9.6	19.6	1,127
20	5	5.28	3.18	0.58	1.14	0.10	63.6	11.6	22.8	1,045
30	5	4.26	3.22	0.54	1.14	0.10	64.4	10.8	22.8	978.9
40	5	2.2	3.22	0.58	1.16	0.04	64.4	11.6	23.2	901.3

1) Comparison of results for separation efficiency by inclination angle

Table 1 shows the results for the separation efficiency of 5 kg of earthworm manure to find the most appropriate inclination for the cylinder by adjusting the angle to 10°, 20°, 30°, and 40°, respectively. The comparison of results for earthworm manure separation by the inclination angle is shown in Fig. 12. and Fig. 13.

Fig. 12 and Fig. 13 show the comparison of results for separation by the inclination angle. At 10° inclination angle, the average weight of EMF, CME, and DE were 3.42, 0.48, and 0.98 kg., accounting for 68.4, 9.6, and 19.6%, respectively. At 20° inclination angle, the average weight of EMF, CME, and DE were 3.18, 0.58, and 1.14 kg, accounting for 63.6, 0.58, and 22.8%, respectively. At 30° inclination angle, the average weight of EMF, CME, and DE were 3.22, 0.54, and 1.14 kg., accounting for 64.4, 10.08, and 22.8%, respectively. At 40° inclination angle, the average weight of EMF, CME, and DE were 3.22, 0.58, and 1.16 kg., accounting for 64.4, 1.16, and 23.2%, respectively.

2) Comparison of results for efficiency of time (Et)

The separation efficiency testing was conducted by adjusting the inclination angle to 10°, 20°, 30°, and 40°, respectively. The comparison of results for the efficiency of time (Et) is shown in Fig. 14.

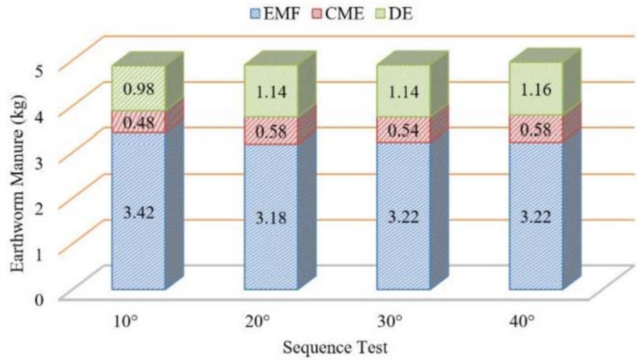

Fig. 12. Comparison of earthworm manure separation by inclination angle

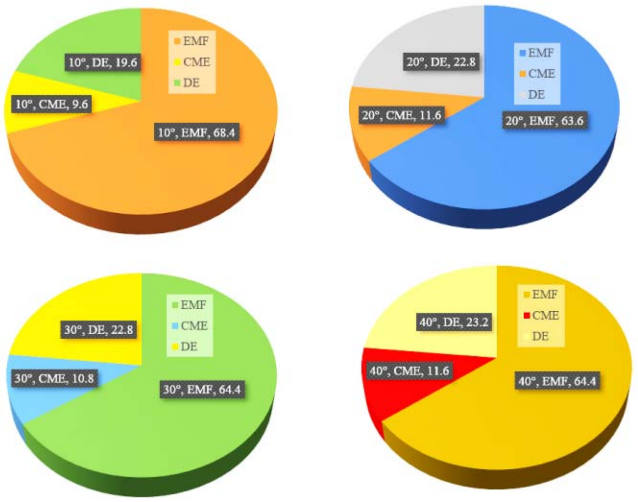

Fig. 13. Comparison of separation percentage by inclination angle

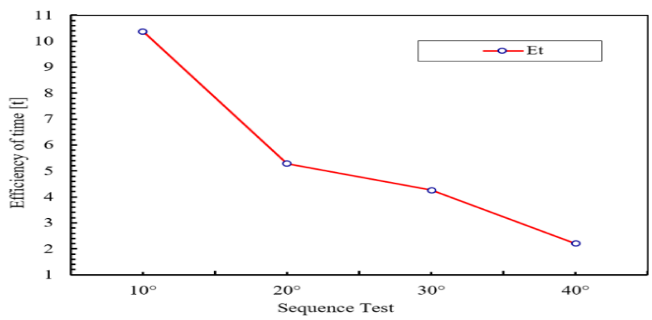

Fig. 14. Comparison of the efficiency of time for earthworm manure separation

Fig. 14 shows a comparison of the results for separation time at different inclination angles. At inclination angles of 10°, 20°, 30°, and 40°, the separation times were 10.389, 5.28, 4.28, and 2.20 mins, respectively.

3) Comparison results of energy

The energy use testing was conducted by adjusting the inclination angle to 10°, 20°, 30°, and 40°, respectively, using the ½ Hp induction motor 230V, 50Hz. The comparison of results for energy use is shown in Fig. 15.

Fig. 15 shows the comparison of results for energy use, voltage (Vt), electric current (CI), and electric power (Pt) for earthworm separation. While having no load, the Vt, CI, and Pt were 228V, 3.64A Pt, and 841.7W, respectively. At 10° inclination angle, the Vt, CI, and Pt were 228V, 3.97A, and 1,127W, respectively. At 20° inclination angle, the Vt, CI, and Pt were 228V, 4.35A, and 1,045W, respectively. At 30° inclination angle, the Vt, CI, and Pt were 228V, 4.51A, and 978.9W respectively. At 40° inclination angle, the Vt, CI, and Pt were 228V, 5.06A, and 901.3W, respectively. The oscilloscope wave, voltage test (Vt), load, and current load (CI) are shown in Fig. 16-20., respectively.

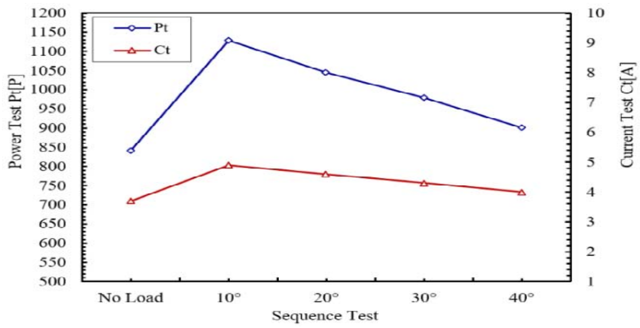

Fig. 15. Comparison of energy use for earthworm separation

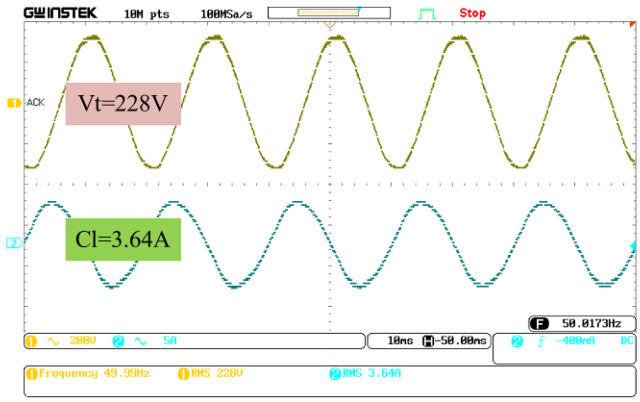

Fig. 16. Voltage wave and test current with no load

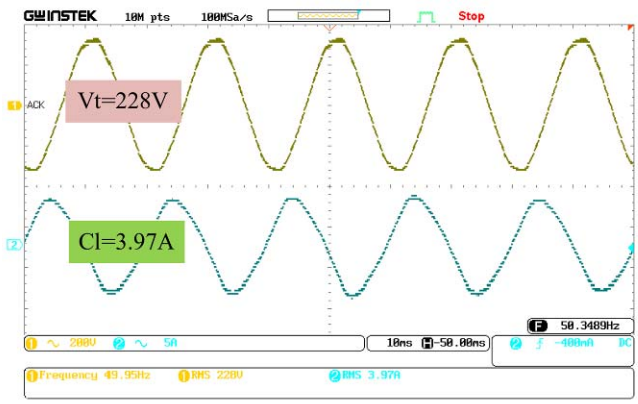

Fig. 17. Voltage wave and test current at 10° inclination angle

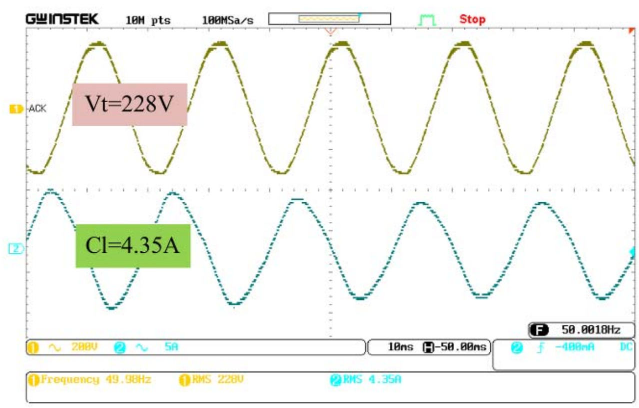

Fig. 18. Voltage wave and test current at 20° inclination angle

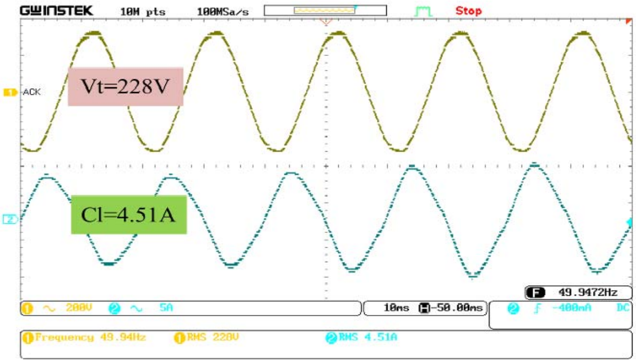

Fig. 19. Voltage wave and test current at 30° inclination angle

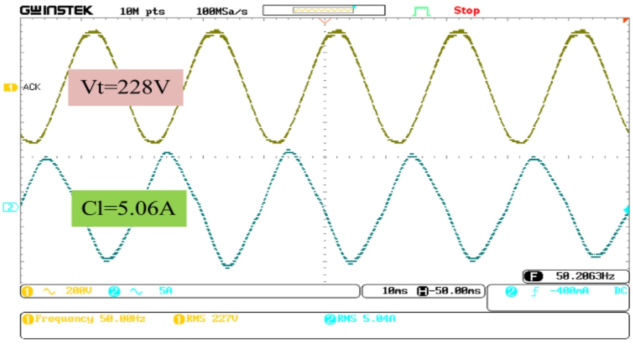

Fig. 20. Voltage wave and test current at 40° inclination angle

Conclusion

This research examined the efficiency of the earthworm waste manure sorting machine (EWSM) using a ½ Hp motor driven with a gear speed reducer at a rotational speed of 48 rpm. The sorting process consisted of three steps: Earthworm Manure Fertilizer (EMF), Coarse Manure and Egg (CME), and Draff and Earthworm (DE). The inclination angle of the cylinder screen could be adjusted to four angles including 10°, 20°, 30°, and 40°. Three values were determined to identify the efficiency of the machine, including separation ratio, energy efficiency, and efficiency of time (Et). Regarding the separation efficiency at 10° inclination angle, the EMF, CME, and DE were 68.4, 9.6, and 19.6 %, respectively. At 20° inclination angle, the EMF, CME, and DE were 63.6, 11.6, and 22.8%, respectively. At 30° inclination angle, the EMF, CME, and DE were 64.4, 10.8, and 22.8%, respectively. At 40° inclination angle, the EMF, CME, and DE were 64.4, 11.6, and 23.2%, respectively. Regarding the Et at 10°, 20°, 30°, and 40°, the separation time was 10.389, 5.28, 4.28, and 2.20 mins, respectively. Regarding energy efficiency, the machine consumed 841.7W while having no load. At inclination angles of 10°, 20°, 30°, it consumed 1,127.8, 1,045, 978.9, and 901.3W, respectively. In conclusion, the test results of EWSM efficiency demonstrated that the inclination of the screen angle at 40° provided the most efficient separation rate at low electric power in the shortest time.

***Authors**: assanee amnuay, E-mail: assanee.a@ubru.ac.th;*
Assoc. Prof. sonthaya gawsombat, E-mail: sonthaya.g@ubru.ac.th;
parinya toommala, E-mail: parinya.t@ubru.ac.th;
Asst. prof. Dr. saktanong wongcharoen,
E-mail: saktanong.w@gmail.com;
Faculty of Industrial Technology, Ubon Ratchathani Rajabhat University, 2 Ratchathani Rd., Mueang Ubon Ratchathani, Ubon Ratchathani, 34000, Thailand.

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