Innovative Systems Design and Engineering
ISSN 2222-1727 (Paper) ISSN 2222-2871 (Online)
Vol.6, No.1, 2015
www.iiste.org

Experimental Determination of the Coefficent of Friction between Palm Nut and Iron

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Abstract

The oil palm **(elaeis guineensis)** commonly called African oil palm produces two very important products – the palm oil and palm kernel oil. They are used for food and industrial purposes. The palm kernel is obtained from the nut by cracking the palm nut using centrifugal machines. The design and operation of the palm nut cracking machines require the knowledge of the coefficient of friction between the palm nut and the metal (iron) that is used to make the cracking drum. The necessary coefficients of friction have therefore been experimentally determined. The coefficient of friction between dry palm nut and iron is 0.36, that between oil lubricated palm nut and iron is 0.30 a decrease of 17% and the coefficient of friction between dry palm fruit fiber and iron is 0.37.

Keywords: Experimentally, Determine, Coefficient, Friction, Palm, Nut.

1.0 INTRODUCTION

The oil palm *(elaeis guineensis)* is commonly called African oil palm. This is because it is known to be native to west and southwest Africa and is common in the area between Angola and the Gambia, (Wikipedia, 2014), the area that was then known as the **gulf of guinea**. In Nigeria, the oil palm belt is known to include the states of Abia, Anambra, Bayelsa, Akwa – Ibom, Cross River, Delta, Ebonyi, Ekiti, Enugu, Ondo, Ogun, Osun, Oyo, Imo and Rivers, (Businessday, 2014). In the 1950s and 1960s, Nigeria was the largest producer of crude palm oil world over, commanding a market share of 43.0%, supplying 645,000 metric tons (MT) of palm oil annually, across the globe. However, as at the year 2013, despite the increase in the level of production (850,000 MT per annum), Nigeria is only the fifth largest producer of palm oil, Indonesia being the first (www.worldpalmoilproduction.com 2013).

Palm produce has many important uses in human life. The two main products obtainable from the oil palm industry are:

(i) Palm Oil, red in color is the oil obtained from the mesocarp of the palm fruit, and
(ii) Palm Kernel Oil (PKO), this is the oil obtained from the palm kernel
Both of these oils are used (Businessday, 2014),
(i) as food i.e. as cooking oil, deep frying oil, margarines, shortenings, spreads, confectionary fats, ice creams etc, and
(ii) In industry for the manufacture of medicine, soap, cosmetics, detergents, lubricating oils, grease, paints etc.

The palm nut from which the palm kernel and consequently the PKO are obtained is one of the products after the palm oil has been extracted from the palm fruits. In order to obtain the palm kernel, the palm nut has to be cracked. The cracking of palm nuts in commercial quantities is done by the use of palm nut cracking machines. Machines of various kinds using various principles have been in use in the past. However, at present most palm nut cracking machines being operated in Nigeria are centrifugal machines that throw the nuts on stationary drums or cracking rings.

During cracking, the impact between the palm nut and the cracking ring is oblique. Therefore the impact force has a component that is normal and a component that is tangential to the surfaces of contact. While the normal component of the reaction force stops the movement of the palm nut in the radial direction, the friction force between the surfaces stops the movement of the nut in the tangential direction (see fig.1).

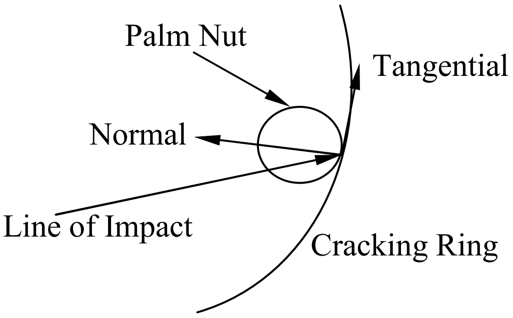

Fig.1: Impact of Palm Nut and Cracking Ring Showing the Line of Impact, Normal and Tangential Directions.

As the impact between the palm nut and the cracking drum develops, the friction force between the palm nut and the drum also develops instantly and becomes equal to the tangential component of the impact force, thus stopping the palm nut from slipping. Therefore the coefficient of friction between the palm nut and the cracking drum (iron) is a necessity in the analysis of the impact forces and stresses. The coefficient of friction is also necessary in the analysis of wear in the cracking ring. Consequently, a friction measuring (tilting plane) instrument was designed and manufactured.

2.0 EQUIPMENT DESIGN AND MANUFACTURE

From the several methods for the measurement of the coefficient of friction between two surfaces that exist, the tilting plane method was chosen [Halling J.]. This was due to its simplicity and the nature of the surfaces between which the coefficient of friction was to be measured.

2.1 THEORY

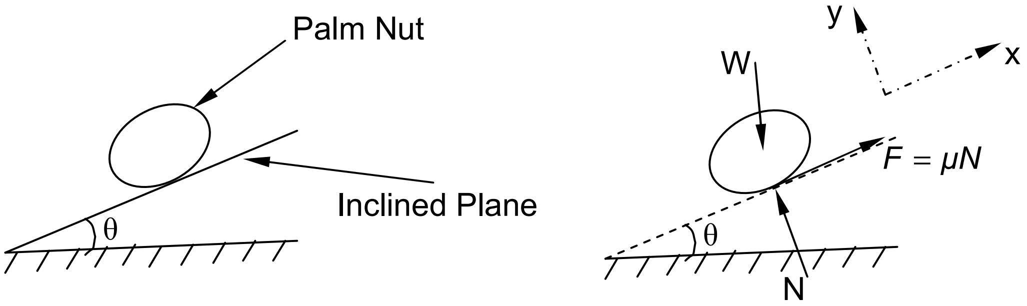

Fig. 3.2: (a) Palm Nut Placed on an Inclined Plane.
(b) Free – Body – Diagram of Palm Nut.

Fig..2(a) represents a palm nut placed on an inclined plane while Fig. 2(b) is the free – body – diagram of the palm nut. With the notation on the figure, *W* represents the weight of the palm nut, *N* represents the normal reaction force, F = μN is the friction force and μ is the coefficient of friction between the palm nut and the surface. At a particular angle of inclination (angle of repose) the nut will tend to either slide or roll down the inline. At this point of impending motion of the palm nut, summing forces in the x and y directions give,

$$\sum F_x = \mu N - W\sin\theta = 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3.1)$$

$$\sum F_y = N - W\cos\theta = 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3.2)$$

Solving equation 3.1 by equation 3.2 simultaneously yields,

$$\mu = \tan\theta \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3.3)$$

Thus the coefficient of friction between the palm nut and the inclined surface is equal to the tangent of the angle of inclination. Consequently, the coefficient of friction the size and weight of the palm nut but depends only on the angle of inclination of the plane.

2.2 EQUIPMENT DESIGN

Fig. 3: Photograph of Tilting Plane Instrument

The tilting plane instrument was designed to have a thin iron plate as the tilting plane which is pivoted at one end of a wooden base plate through a 5mm pivot rod. The two ends of the rod were threaded with M10 thread to take 10mm nuts to hold the rod in place. The two ends of the rod pass through holes in brackets nailed to the wooden plate. A quarter protractor, cut from a 360^o protractor is also attached to the wooden base plate through the pivot rod and held in place with the nut and washer. Nailed to the sides of the free end of the base plate are two flat 10mm x 60mm x 300mm wooden brackets. At the upper ends of the wooden brackets are 10mm diameter holes drilled to hold a 10mm rod treaded at the ends. A wooden pulley was also mounted on the rod to aid the process of tilting the plane. A rope attached to the free end of the tilting plane through a 2mm hole drilled near the free end of the tilting plane passes over the wooden pulley. During each experiment, the rope is pulled to raise the free end of the tilting plane in order to gradually increase the angle of inclination of the tilting plane. Figure 3 is a photograph of the assembled instrument, and the production.

3.0 EXPERIMENTS

3.1 DRY FRICTION BEWEEN PALM NUTS AND IRON

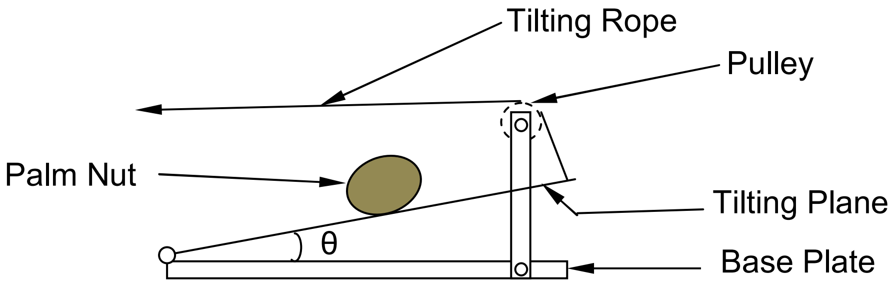

Fig. 3.4: Schematic Diagram of Tilting Plane Mechanism

Fig. 3.4 shows a schematic diagram of the tilting plane mechanism that was used in the experiments to determine the coefficient of friction between the palm nuts and iron.

In order to have enough palm nuts for all the experiments, some quantity of palm nuts (tenera) was acquired from the Bayelsa Palm Company. The palm nuts were sun dried for over ten (10) days to reduce the moisture content and kept in a dry place before the experiments were performed. This was done in accordance with the required cracking conditions shown in the report of Gbadam et al, (2009).

From Eq.3.3 it was deduced that the coefficient of friction between the palm nuts and iron does not depend on nut size. Thus fifty (50) nuts were randomly selected and used for the friction test.

During each test, the flat iron plate (tilting plane) was first cleaned with a smooth sand paper (GXK51 – LD P 240) to remove any surface contamination before a nut was placed on the surface. Then the tilting rope was pulled gradually to raise the tilting plane until the nut either starts to slide or roll down the plane. The pulling of the rope was then stopped and the angle of inclination (angle of repose) of the tilting iron plate was read from the protractor and recoded. (See appendices 1,2and3) The tangent of the angle of repose being equal to the coefficient of friction was calculated and also recorded.

3.2 OIL SMEAR FRICTION TEST

In the oil palm processing plant, palm nuts are usually wet with oil and therefore the contact between palm nuts and the iron surfaces are lubricated. Thus the coefficient of friction between the palm nuts and iron is expected to be lower than that between dry palm nuts and iron. It was therefore necessary to estimate the coefficient of friction between palm nuts and iron with palm oil lubrication.

Consequently, fifty (50) nuts were arbitrarily chosen for the test. Before each test, palm oil was smeared on the test surface before the nut is placed on the tilting plate and the test was carried out as described in the above section.

3.3 PALM FRUIT FIBER FRICTION TEST

Also in the oil palm processing plant, the fiber is usually separated from the nuts and transported by the use of fans. It was observed in the cause of this project that the fibers cause very severe erosion on the fan blades and consequently, the fan blades are replaced very frequently. Since friction between the stream of fibers and the fan blade material must be playing a significant role in the erosion, it is necessary to estimate the coefficient of friction between the two materials. Thus the coefficient of friction between the palm fruit fiber and iron was experimentally determined.

In order to test for the coefficient of friction between palm fruit fibers and iron, a small piece of iron was wrapped with fibers with the aid of glue. When placed on the tilting plane, the iron piece was so wrapped that only the fiber made contact with the tilting plane. The tilting plane was then raised until the specimen starts to slide. The angle of repose was then read from the protractor attached to the side of the instrument and recorded (appendix 3). A total of fifty (50) tests were performed.

4.0 DATA ANALYSYS

The coefficients of friction between dry palm nuts and iron, dry palm nuts and oil smeared surface, and dry palm fruit fiber and iron are as shown in table 3.1. It was observed that the coefficient of friction between dry palm nuts and iron and between dry palm fruit fiber and iron are very close. This can be explained by the fact that embedded fiber, lines the surface of the palm nut. Thus the palm nut contacts the iron surface through the palm nut fiber.

Table 3.1: COEFFICIENT OF FRICTION.

S/#	TYPE OF FRICTION	AVERAGE COEFFICIET FRICTION	STANDARD DEVIATION
1.	Dry Palm Nut and Iron	0.36	0.034
2.	Dry Palm nut and oil smeared Surface	0.30	0.033
3.	Dry Palm Fruit Fiber and iron	0.37	0.034

It was also observed that the coefficient of friction between the dry palm nut and oil smeared surface shows a decrease of about 17%. This could have a significant effect on the cracking efficiency of the cracking machine. It is therefore recommended that both the palm nuts surfaces and the surface of the cracking ring should be kept dry during cracking of the palm nuts.

CONCLUSION

The coefficients of friction for dry palm nuts and iron, oil lubricated palm nuts and iron and dry palm fruit fiber have been determined using the inclined plane method. This means that the friction component of the cracking forces during the cracking of palm nuts using the centrifugal force method can be determined analytically. The knowledge of the coefficient of friction will be helpful in the study of the wear problems in palm nut cracking machines.

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APPENDIX 1

COEFFICIENT OF FRICTION BETWEEN PALM NUTS AND IRON

S/#	ANGLE OF REPOSE (θ)	COEFFICIENT OF FRICTION (μ)		S/#	ANGLE OF REPOSE (θ)	COEFFICIENT OF FRICTION (μ)
1.	20	0.364		26.	17	0.306
2.	17	0.306		27.	18	0.325
3.	20	0.364		28.	22	0.404
4.	20	0.364		29.	19	0.344
5.	22	0.404		30.	17	0.306
6.	20	0.364		31.	20	0.364
7.	20	0.364		32.	18	0.325
8.	19	0.344		33.	19	0.344
9.	18	0.325		34.	20	0.364
10,	21	0.384		35.	19	0.344
11.	20	0.364		36.	20	0.364
12.	20	0.364		37.	20	0.364
13.	21	0.384		38.	21	0.384
14.	22	0.404		39.	21	0.384
15.	19	0.344		40.	19	0.344
16.	22	0.404		41.	21	0.384
17.	20	0.364		42.	21	0.384
18.	20	0.364		43.	18	0.325
19.	18	0.325		44.	18	0.325
20.	22	0.404		45.	20	0.364
21.	19	0.344		46.	19	0.344
22.	20	0.364		47.	19	0.344
23.	21	0.384		48.	18	0.325
24.	20	0.364		49.	21	0.384
25.	21	0.384		50.	20	0.364
					Average	0.359
					Standard Deviation	0.034

APPENDIX 2
COEFFICIENT OF FRICTION BETWEEN PALM NUTS AND IRON WITH OIL SMEAR

S/#	**ANGLE OF REPOSE (θ)**	**COEFFICIENT OF FRICTION (μ)**		**S/#**	**ANGLE OF REPOSE (θ)**	**COEFFICIENT OF FRICTION (μ)**
1.	16	0.287		26.	17	0.306
2.	17	0.306		27.	17	0.306
3.	20	0.364		28.	17	0.306
4.	18	0.325		29.	15	0.268
5.	17	0.306		30.	17	0.306
6.	17	0.306		31.	16	0.287
7.	18	0.325		32.	18	0.325
8.	17	0.306		33.	16	0.287
9.	16	0.287		34.	17	0.306
10,	17	0.306		35.	17	0.306
11.	16	0.287		36.	16	0.287
12.	16	0.287		37.	16	0.287
13.	18	0.325		38.	17	0.306
14.	16	0.287		39.	18	0.325
15.	17	0.306		40.	17	0.306
16.	17	0.306		41.	17	0.306
17.	16	0.287		42.	16	0.287
18.	15	0.268		43.	16	0.287
19.	18	0.325		44.	17	0.306
20.	16	0.287		45.	18	0.325
21.	16	0.287		46.	17	0.306
22.	20	0.364		47.	18	0.325
23.	17	0.306		48.	16	0.287
24.	16	0.287		49.	17	0.306
25.	17	0.306		50.	17	0.306
					Average	0.304
					Standard Deviation	0.033

APPENDIX 3
COEFFICIENT OF FRICTION BETWEEN PALM FRUIT FIBER AND IRON

S/#	ANGLE OF REPOSE (θ)	COEFFICIENT OF FRICTION (μ)		S/#	ANGLE OF REPOSE (θ)	COEFFICIENT OF FRICTION (μ)
1.	20	0.364		26.	20	0.364
2.	22	0.404		27.	20	0.364
3.	20	0.364		28.	19	0.344
4.	21	0.384		29.	22	0.404
5.	20	0.364		30.	18	0.325
6.	21	0.384		31.	20	0.364
7.	19	0.344		32.	20	0.364
8.	20	0.364		33.	19	0.344
9.	22	0.404		34.	20	0.364
10,	18	0.325		35.	22	0.404
11.	20	0.364		36.	20	0.364
12.	20	0.364		37.	22	0.404
13.	22	0.404		38.	19	0.344
14.	22	0.404		39.	20	0.364
15.	21	0.384		40.	20	0.364
16.	21	0.384		41.	21	0.384
17.	23	0.424		42.	21	0.384
18.	20	0.364		43.	19	0.344
19.	20	0.364		44.	20	0.364
20.	21	0.384		45.	20	0.364
21.	19	0.344		46.	21	0.384
22.	20	0.364		47.	20	0.364
23.	19	0.344		48.	19	0.344
24.	20	0.364		49.	20	0.364
25.	21	0.384		50.	21	0.384
					Average	0.370
					Standard Deviation	0.034