MANUFACTURING AND PERFORMANCE EVALUATION OF A PROTOTYPE WOOD CHIPPING MACHINE TO PRODUCE MINI-CHIPS

M.A. Tawfk* **M.I. El-Didamony****

ABSTRACT

The oversize wood chips are existing in the conventional disc chipper production even with tuning the chipper settings which is not convenient to be used in the some applications that need to small sizes chips as biomass pellets or poultry litter for instances, hence there is an urgent need to produce mini-chips (M_{CHIPS}) to become abundant for wide range of agricultural utilization within the farm. Thus, the present study aims to manufacture and evaluate the performance a local made prototype wood chipping machine by providing the conventional wood disc chipper with built-in swinging hammer mill and concave screen behind the cutting disc on the same rotating shaft using the pruning residues of mango trees to produce M_{CHIPS} with high quality (uniform chips with minimum fines) and low energy requirement. The performance of the chipping machine was evaluated under operational variables including; three cutting rotational speeds of 750, 1000 and 1250 rpm corresponding to peripheral speeds of 17.66, 23.55 and 29.43 m/s, respectively, three cutting angles of 48°, 50°, 54° and 58°, three concave screen sizes of 12, 16 and 20 mm, where the hammers has the same rotational speed of the cutting disc. The machine performance was investigated taking into consideration the machine productivity, particle size distribution, and energy requirement. The results indicated that, it is recommended to use the prototype chipping machine at cutting speed of 1000 rpm (23.55 m/s), cutting angle of 58° and screen size of 16 m to obtain the best M_{CHIPS} particle size distribution (M_{CHIPS} ≤3 mm= 6.05 %, M_{CHIPS} >3-8 mm= 24.07 %, M_{CHIPS} >8-12mm = 39.95% and M_{CHIPS} >12-16mm=29.93 %) to achieve regular M_{CHIPS} with minimum fines at machine productivity of 1.40 Mg/h and consumed energy of 12.35 kW.h/Mg.

Keywords: *prototype chipping machine, wood disc chipper, hammer mill, pruning residues, mini-chips, machine performance*

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INTRODUCTION

Agricultural residues represent very serious problem in Egypt facing the people and government economically and environmentally. It is possible to obtain many benefits by exploiting all of these residues through some applications like animal feed, organic fertilization, animal bedding, bioenergy generation and many other usages in the farm **(Bakr *et al.*, 2016)**. Therefore , the concept of utilizing the biomass as a potential renewable energy resource to produce heat, electricity, and power become more interesting in last few decades **(Atyia *et al.*, 2017)**. Exploiting the wheat straw, rice straw, cotton stalks, corn stover , bagasse or even rice hull are very common in Egypt as biomass feedstock for generating bioenergy or even in animal feed and bedding ,but the utilization of the fruit trees pruning residues is very rear. Recently, Egyptian farms produce about 30 Mega ton annually of agricultural residues where fruit tree pruning contribute with 12.3% of total national residues **(FAO, 2017)**.Sharkia governorate comes in the second place of the national production of mango, so the mango pruning residues is abundant but unfortunately no recent or previous attempts to be used in different purposes except firing. Simultaneously, converting the tree pruning to small chips can be promote and upgrade these solid residues in very wide range of agricultural applications; such as, animal feeding, biomass pellets or even poultry litter. Chipping process is preferable to smash the solid residues due to it produces predictable properties particles **(Di Fulvio *et al.*, 2015)**. Length size distribution and percentage of fines (small-size particles) are considered important quality parameters **(Jensen *et al.*, 2004),** where the achieving of the right length-size distribution is tough challenge **(Spinelli *et al.*, 2005)**.The present work is focused on producing uniform small-sizes wood chips to be used different applications by the comminution of mango tree pruning using wood chipper. Chippers are comminution machines used to produce wood chips and can be divided into two types; the disc and drum chipper, where the disc chipper has simple design and higher energy efficiency than the drum chipper, despite the drum chipper has more productivity but it’s insignificant. **(Spinelli *et al.*, 2013).** There are many critical factors affecting the chipper performance and consequently the production quality such as; cutting angles, cutting speed and chips length settings (**Reczulski, 2015**) as well as height of knife from disc, logs moisture content, feeding rate and many others. The spout angle (ε) and knife velocity can control chips geometry **(Reczulski, 2016),** while the cutting angles are involved: the cutting angle or the rake angle (γ), sharpness angle (β) and clearance angle (α) where the sum of the three angles is 90° **(Abdellah *et al.*, 2011)**, as depicted in Fig.(1). The sharpness angle can be lied between 30-45° **(Gonçalves and Néri, 2005)**, while the clearance angle between 5 to 8° **(Gendek, A. and A. Nawrocka, 2014).** It was noticed that wood chips length can be varied by using different heights of cutting knife from the disc surface in the recommended range of 18.1 to 21.1 mm for the knives with constant width **(Hellström *et al.*, 2009).** It is very essential to operate the chipper at cutting speed not exceed 25 m/s to avoid the too small size chips **(Reczulski 2013)** because the excessive cutting speed in trial to increase the machine efficiency is inappropriate **(Hernandez and Jacques, 1997),** also using very high or low logs moisture content can lead to produce a large amounts of the small chips and fines which declines the chips quality and gives more emission **(Hartmann *et al.*, 2006)**. Regarding the small-size (mini-chips) chips production, the conventional chipper can be equipped with machines provided with chips -breaker or screens to reduce the over-size chips **(Facello *et al.*, 2013)** and the screen size can affect significantly **(Nati *et al.*, 2010)**. Moreover, the production of mini-chips Accordingly, the main goal of the present study is manufacturing and evaluating the performance a local made chipping machine by providing the conventional wood disc chipper with built-in swinging hammer mill with concave screen behind the cutting disc as integration system for chipping the pruning residues of mango trees to produce regular mini-chips with minimum fines (small-size chips) to be used in wide range of agricultural applications such as, animal feeding, biomass pellets and poultry litter because the oversize chip is existing in the conventional disc chipper even with tuning the chipper settings.

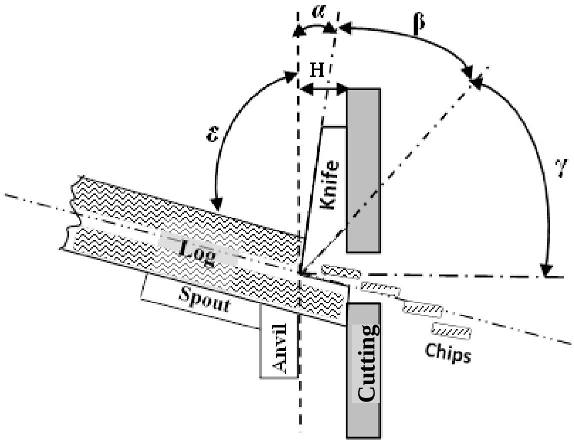

Fig. (1): The chipping angles (Abdellah *et al.*, 2011)

MATERIALS AND METHODS

The practical experiments were carried out at Abou Hammad district, Sharkia, Egypt to evaluate the performance of a locally manufactured a prototype chipping machine including basically of a wood disc chipper equipped with a swinging hammer mill behind the cutting disc in one synergic machine to produce uniform mini-chips with less fines and power requirement.

1. Materials

1.1. Wood logs characteristics

The pruning residues of mango trees were collected from a private mango orchard at Abou Hammad district with the average moisture content range of 14%. Due to the chipping of smaller logs diameters gives the chipper inferior quality chips **(Krajnc and Dolšak, 2014)**, so the average diameter of the pruning logs selected in the range from 40 to 120 mm.

1.2. The prototype chipping machine specifications:

The prototype machine consists of main frame, chipping machine (conventional wood disc chipper equipped with swinging hammer mill), transmission system and power unit, as illustrated in Fig.(2).

1.2.1. The main Frame

The main frame is a rectangular shape base which made of steel iron with overall length of 1495 mm and 500 mm in width with 100 mm in thickness. This frame is carrying the prototype chipping machine (disc chipper equipped with hammer mill) and electric motor. The base provided with inverted U-shaped stand constructed from iron bars. The overall dimensions of the machine stand were 515 mm in length, 500 mm for width. Electric motor base constructed of iron sheet and fixed to the base with 4 bolts with dimensions of 7 mm thickness, 450 mm length and 450 mm width.

1.2.2. The prototype chipping machine

The construction features of the prototype machine can be described as follows:

1.2.2.1. Machine case

The case of machine is the accommodation of the cutting disc and the hammer mill that constructed of cylindrical-shaped iron sheet with 5 mm thickness, 300 mm width and 750 mm in diameter. The volute was provided with a folded gate at the upper circumferential part to facilitate reaching to the internal components for repairing and maintenance purposes to control the logs path towards the cutting disc through the machine volute an inclined conical side chute was used as feeding duct with rectangular inlet port (320×162.5 mm), as displayed in Fig.(2). The output port (200×300 mm) can deliver the received M_{CHIPS} from the hammer mill concave screen

1.2.2.2. Cutting disc

The cutter disc is a high rotating plate with diameter 450 mm provided with sharpened knives that made from iron with 20 mm thickness. The plate is attached strictly to a thermal hardened shaft that made of iron bar metal with dimensions of 50 mm diameter and 659 mm length and rotates throughout a two high speed bearings that fixed on the machine stand, where one end coupled to the drive pulley and the other end extended to carry both the cutting disc and the hammers simultaneously. Three cutting knives fixed on the radial direction of the disc with regular angles (120°), as shown in Fig. (3). Every knife was made from hard steel 52 carbons, with dimensions of 200 mm length and 70 mm width.

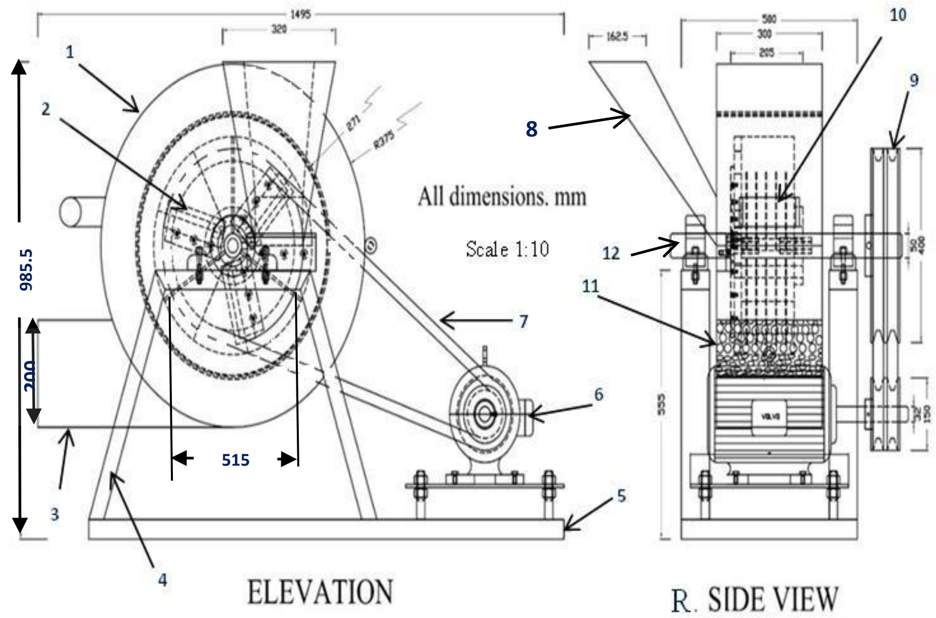

Fig.(2): The prototype chipping machine.

1- Machine case ; 2- Cutting disc; 3- Outlet port; 4- Machine stand; 5- The base; 6- Electric motor; 7- Belt; 8- Input chute; 9- Pulley; 10- Hammer mill; 11- Concave screen; 12- Machine shaft

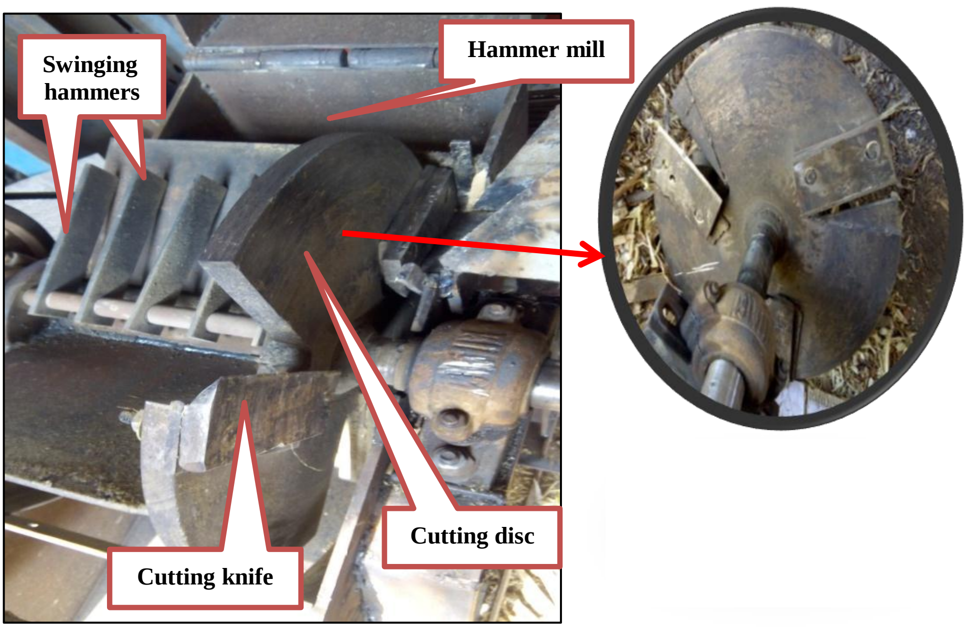

Fig.(3) : Internal components of the prototype chipping machine.

1.2.2.3. Hammer mill

As illustrated in Fig.(3), hammer mill is fixed behind cutting disc, where it rotates by the same extended shaft of the cutting disc which is consists of three hammers groups .Each group has an iron bar with dimensions of 25 mm diameter, 195 mm length. Every bar has 5 hardened swinging hammers with total number of 15 hammers. The hammers fixed with bars that made from hard steel sheet, with dimensions of 50 mm width, 167 mm length and 3 mm thickness for each hammer. Accordingly, the outer diameter of the rotating hammers is 384 mm.

1.2.2.4. Transmission system and power unit

The electric motor with total power of 11 kW at 1500 rpm rotational speed was used to transmit motion to the cutting disc using the pulleys and V-belt unit by operating the drive pulley that fixed on the disc shaft. One pulley fixed on the electric motor shaft with diameter of 150 mm and the second pulley fixed on cutter disc shaft. To obtain four different rotational speeds for the disc ranging between 500 to 1250 rpm, four different diameters of cutting disc shaft pulley were used.

2. Methods

2.1. Experiment's conditions

In the practical experiments, the manual drop-feeding methods using logs with total weight of about 30 kg/ min as an average load that suit the small-scale operations **(Spinelli and Hartsough, 2001)** was used. The manufactured chipping machine performance was evaluated using a constant sharpness angle (β) of 30°, spout angle (ε) of 45° and knife height (H) of 20 mm above the disc surface under the following variables:

-Three cutting angles (γ) of 48°, 50°, 54° and 58°, corresponding to clearance angles (α) of 12, 10, 6 and 2°.

- Three cutting rotational speed of 750, 1000 and 1250 rpm corresponding to disc/hammers peripheral speeds of 17.66, 23.55 and 29.43 m/s, respectively

- Three concave screen size (diameter) of 12, 16 and 20 mm.

2.2. Particle size distribution

Regarding the size distribution of chips, the M_{CHIPS} was classified into medium chips (16-45mm), small-size (3.15-16 mm) and fines (< 3.15 mm) (**Assirelli *et al.*,2013),** whereas the main fraction (80%) should be lied in range 3.15-16 mm and fines (< 3 mm) must not exceed 5% to obtained high quality chips **(Alakangas *et al.*, 2006).** Hence, four sieves of 3, 8, 12 and 16 mm were used to classify the chip by weight into five categories of $M_{CHIPS} \leq 3$ mm, M_{CHIPS} >3-8 mm, M_{CHIPS} >8-12mm , M_{CHIPS} >12-16 and M_{CHIPS} >16mm.

2.3. Measuring and Determinations

The machine performance was evaluated with taking into consideration the following indicators:

2.3.1 Logs moisture content

The moisture content of mango trees pruning determined in three replicates by drying the samples in an electric oven furnace (Binder ED-53).

2.3.2. Machine productivity

An electrical balance scale (OHAUS- U.S.A) with maximum reading of 3000 g and accuracy of 0.1 was used for weighting the delivered wood chips samples. Then, the chipping machine productivity was calculated using the following relation:

$$M_p = \frac{W_{ch}}{T} \times 3.6 \quad \text{……………………. (1)}$$

Where:

M_p =machine productivity, Mg/h

W_{ch}= mass of wood chips, g

T = consumed time, s

2.3.3. Power and energy requirement

A digital clamp meter (Super clamp meter 700 k -Japan) with an accuracy (± 0. 5 Ampere) was used for measuring current intensity and voltage respectively. Accordingly, the following formula was used to estimate the required power **(Ibrahim, 1982):**

$$P = \frac{\sqrt{3} I.V \cos\theta}{1000} \quad \text{……………… (2)}$$

Where:

P= Required power, kW

I= line current strength in Amperes.
V = Potential strength (voltage) being equal to 380V.
$\cos\theta$ = power factor (being 0.7).
The specific energy requirement (kW.h/Mg) was calculated by using the following equation:

$$\textit{The}\ \text{specific energy requirement (kW.h/Mg)} = \frac{\text{The required power (kW)}}{\text{machine productivity (Mg/h)}} \quad \ldots. (3)$$

RESULT AND DISCUSSION

1- The prototype chipping machine productivity

Fig. (4) depicts the effect of cutting speed and cutting angle (rake angle) on the prototype disc chipper productivity under different screen sizes of the hammer mill concave. It was noticed that, the machine productivity increased consistently by increasing the cutting speed from 750 to 1250 rpm (17.66 to 29.43 m/s) and tends to increase very slightly with further increase of cutting speed to 1250 rpm (29.43 m/s) at small screen size of 12 mm ,while this increase is clear at larger screen size of 16 and 20 mm. The productivity increases as cutting angle increases when the other variables remained constant. Moreover, the productivity increased by increasing the concave screen size from 12 to 16 mm, but a rapid increase was observed by using a larger screen size up to 20 mm. Concerning the relations between cutting speed and the machine productivity, the obtained results revealed that, increasing cutting speed from 17.66 to 29.43 m/s , the highest machine productivity at cutting angle of 58° and screen size of 20 mm was increased from 1.544 to 1.700 Mg/h, but trend started to decline to reach 1.470 Mg/h at cutting speed 29.43 m/s, whilst the lowest machine productivity at cutting angle 48° and screen size 12 mm increased very slightly from 0.658 to .710 Mg/h and retarded to be 0.578 Mg/h at high disc speed. This is because low cutting speed produces irregular, big chips and causing more chips deformation due to the jumping phenomenon. This phenomenon means the logs feeding before the cutting disc finished chipping the previous one and this is gave large wood pieces which take more time to be shattered by the swinging hammers especially at low concave screen size. Also the excessive cutting speed means more number of cuts per wood piece in unit of time causing noticeable reduction in the process and a large amount of the small-size chips or even fines would be expected. The data show that the increase of cutting angle (rake angle) from 48 to 58° gives more chips production under all variables of the experiment. This because the increase of cutting angle (γ) will be companied with a decrease the clearance angle (α) which means the cutting process will occur before the contact of log with the cutting disc surface and the shear stress adjacent the knife edge will be parallel to the log direction and then thinner chips will be produce and consequently the productivity will increase especially at high cutting speed. Hence, the highest value of machine productivity of 1.700 Mg/h was obtained at cutting speed 1000 rpm (23.55 m/s), cutting angle 55° and screen size of 20 mm, whereas the lowest value of machine productivity of 0.640 Mg/h was recorded at cutting speed 1250 rpm (29.43 m/s), cutting angle 48° and screen size of 20 mm.

2- Mini-chips size distribution

Fig.(5) illustrate the size distribution of the sieved M_{CHIPS} that produced by the prototype chipping machine under different cutting speeds, cutting angles (knife rake angles) and screen sizes. The obtained results show that the large fines (25%) was observed at lower cutting speed of 750 rpm(17.66 m/s) and cutting angle 48° at small screen size of 12 mm and this not expected particularly for low cutting speed. This may be attributed to the increase of deformed big chips that produced due lower cutting angle and the big clearance angle which lead to remained relatively long time under the impacts of the hammer mill especially when the concave screen size is small, while at the same speed and angle, less fines was recorded at large screen size of 20 mm. At cutting speed of 750 (17.66) and 1000 rpm (23.55 m/s) with constant screen size, by increasing cutting angle from 48° to 58° produces more M_{CHIPS} (3-12 mm) on the account of large chips and the fines tends to decrease, but the screen size of 16mm still has less fines comparing to the screen size 12 mm. This because the shear stress become parallel to the grain direction at high cutting angle and more thinner chips will produce but these cutting speed may give thinner chips without cracks, so despite the impacts of swinging hammers the fines from thinner chips tends decrease.

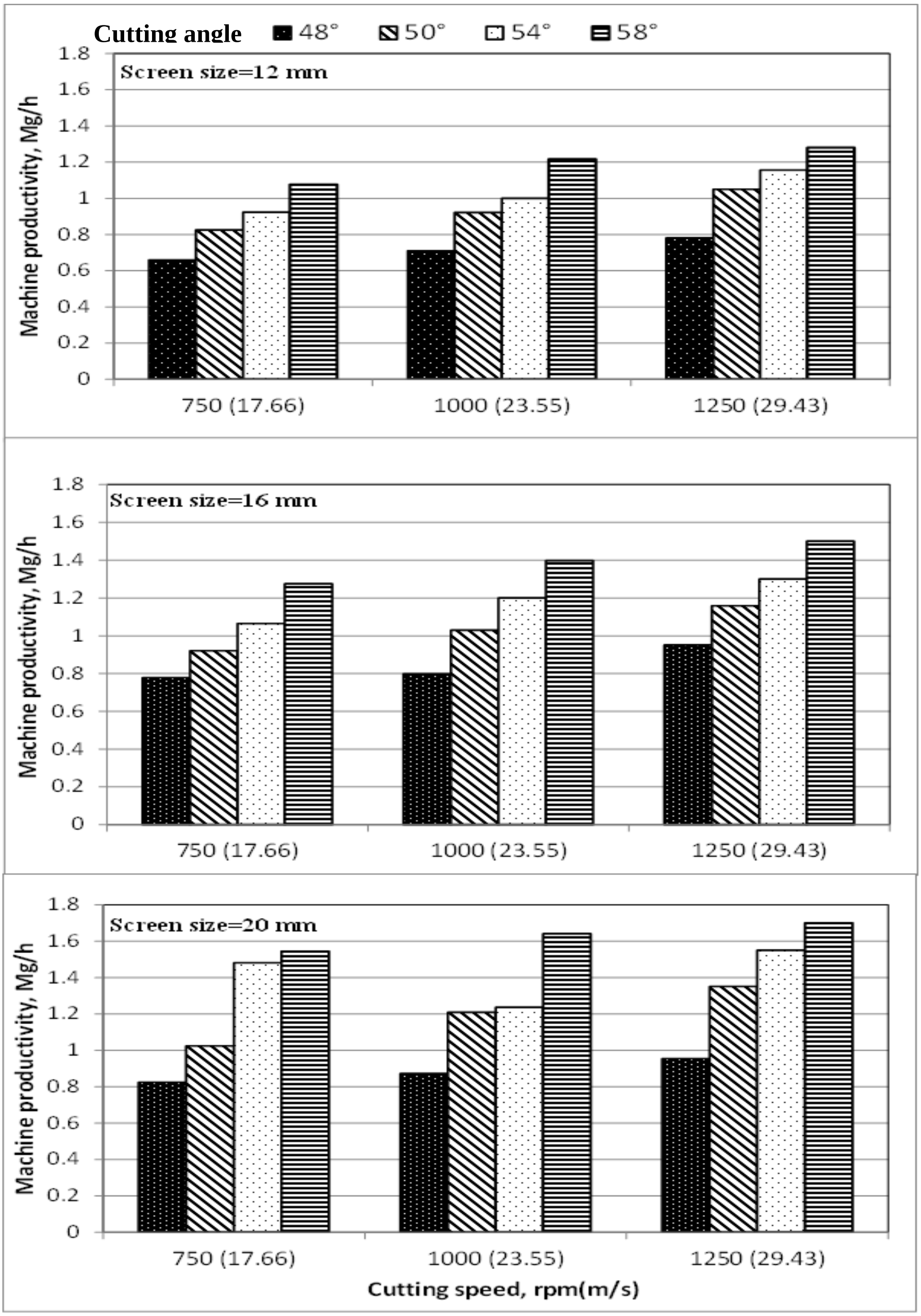

Fig.(4): Effect of cutting speed and cutting angle (rake angle) on the machine productivity at different screen sizes.

It was observed that the increase of cutting speed up to 1250 rpm (29.43 m/s) and screen size from 12 to 16 mm the length category of >3-8 mm increased rapidly and fines decreased. This can be referred to reduction of retention time of the chips in the hammer mill especially in larger screen size of 16 mm. Besides, the increase of cutting angle from 48° to 58° and screen size from 12 to 20 mm at the highest cutting speed of 1250 rpm (29.43 m/s) the fines increased rapidly in adverse behavior comparing to the other cutting speeds where the fines reached its peak at cutting angle of 58°, screen size of 20 mm. This because the high cutting speed gives a very cracked short chips and simultaneously the high cutting angle accompanied with little clearance angle produces thinner wood chips and this resulting in more fines delivered from the hammer mill concave screen. In light of previous literatures, the high quality of wood M_{CHIPS} required the fines (very small length) to be minimized to 5% or less and most of fractions (80%) in range between 3 -16 mm, so the best average length distribution of the M_{CHIPS} has been obtained as follows: $M_{CHIPS} \leq 3$ mm= 6.05 %, M_{CHIPS} >3-8 mm= 24.07 %, M_{CHIPS} >8-12mm = 39.95% and M_{CHIPS} >12-16mm=29.93 %, at cutting speed of 1000 rpm (23.55 m/s) , cutting angle of 58° and screen size 16 mm, as shown in Fig.(6).

3- Energy requirement

The effect **of** cutting speed and cutting angle on the consumed energy that during the chipping process of mango trees pruning using different screen sizes for the hammer mill concave is illustrated in Fig.(7). At constant cutting angle, the obtained data indicated that the increase of cutting speed from 750 to 1250rpm (17.66 to 23.55 m/s) at smaller screen size of 12 mm, the energy requirement is almost quasi-steady value but it tends to increase at high cutting speed of 1250 rpm (29.43 m/s) . At larger screen size of 16 and 20 mm this behavior is different where the consumed energy decreased by increasing the cutting speed from 17.66 to 23.55 m/s due to the increase that occurred in machine productivity is higher than increase in consumed power by the cutting disc and hammers, but any further increase in cutting speed the energy requirement will increase due to the increase of friction between the knife and logs and thus cutting force will increase.

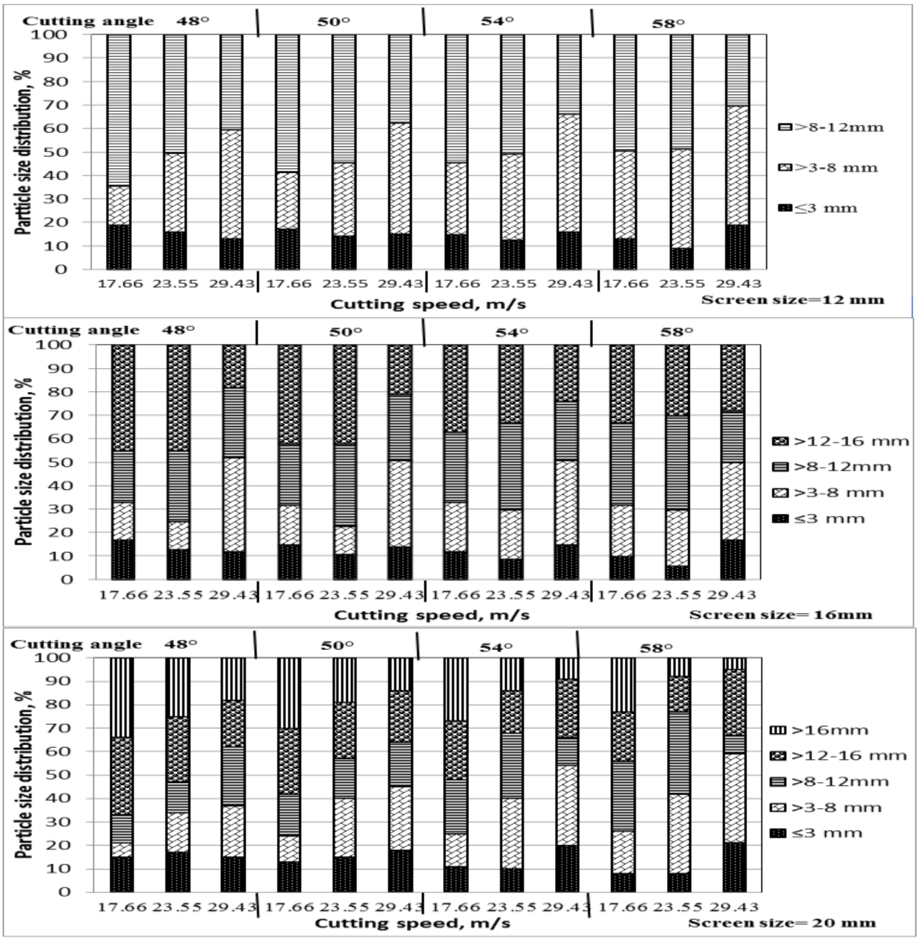

Fig.(5): Effect of cutting speed and cutting angle on particle length distribution of M_{CHIPS} at different screen sizes.

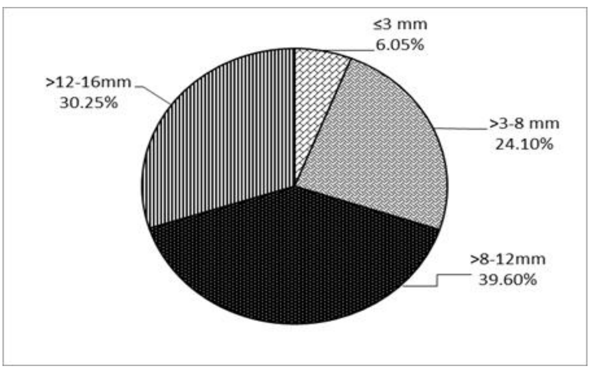

Fig.(6): The best particle length distribution for M_{CHIPS} at cutting speed 23.55 m/s, cutting angle 58° and screen size 16 mm.

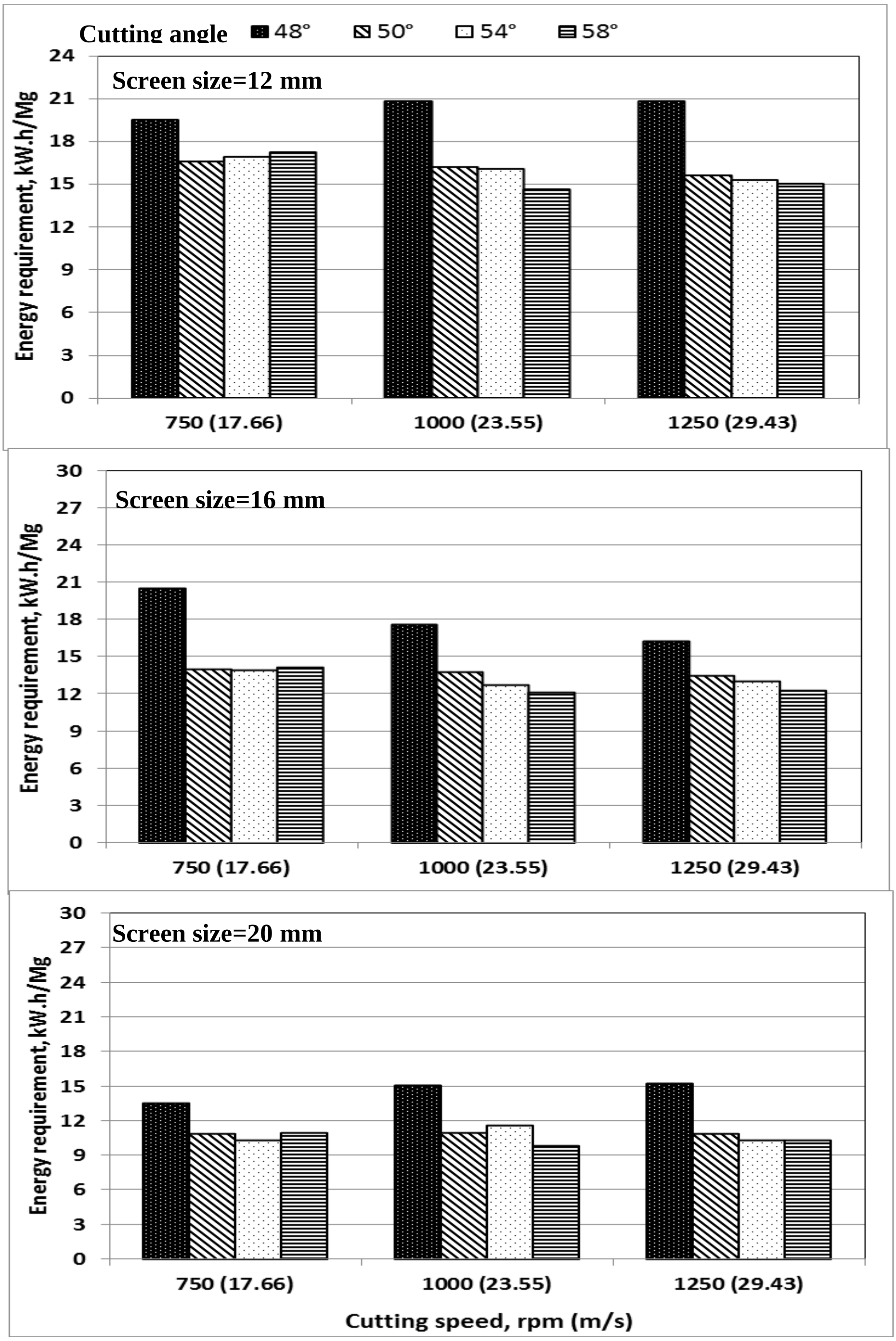

Fig. (7): Effect of cutting speed and cutting angle (rake angle) on the energy requirement for chipping process at different screen sizes.

As general trend, increasing the concave screen size from 12 to 16 mm will decrease the energy requirement remarkably throughout the chipping process when the other variables remained constant. Additionally, the cutting angle affect greatly on the energy requirement for wood chipping process. On one hand, the results indicated that the increase of cutting angle (γ) from 48° to 54° at lower cutting speed of 750 rpm (17.66 m/s), the energy requirement decreased gradually , but adverse trend was occurred using the highest angle of 58°. On the other hand, the increase of cutting angle from 48° to 54° at higher cutting speeds of 1000 and 1250 rpm (23.55 and 29.43 m/s), the energy requirement decreased slightly and tends to remained constant at higher cutting angle of 58°. This because the high cutting angle and speed causing a very high friction between the knife and logs which means more cracks in the chips after that the hammer mill consume less power, simultaneously the low cutting angle means high clearance angle which produces thicker chips and the consumed power by the hammer mill will increase to crush the chips. Hence, there is no doubt that the hammer mill affects the power consumption and consequently the specific energy requirement. Accordingly, the lowest value of specific energy requirement of 9.51 kW.h/Mg was obtained at cutting speed of 1000 rpm (23.55 m/s),cutting angle of 58° and screen size of 20 mm, while the highest value of specific energy requirement of 25.35 kW.h/Mg was recorded at cutting speed of 1250 rpm (29.43 m/s), cutting angle of 48° and screen size of 12 mm. From previous discussion, it was found that, the corresponding energy requirement to the best M_{CHIPS} particle size distribution of 12.35 kW.h/Mg was recorded cutting speed of 1000 rpm (23.55 m/s), cutting angle of 58° and screen size of 16 mm at machine productivity of 1.40 Mg/h. As general note, the machine can produce more productivity with less energy requirement but the excessive fines will be existed.

CONCLUSION

According to the obtained results, it can be concluded that the optimum conditions for operating the prototype chipping machine to produce regular wood mini-chips (M_{CHIPS}) with minimum fines (small-sizes chips) are the cutting speed of 1000 rpm (23.55 m/s), cutting angle of 58° and screen size of 16 m to obtain the best M_{CHIPS} particle size distribution

(M_{CHIPS} ≤3 mm= 6.05 %, M_{CHIPS} >3-8 mm= 24.07 %, M_{CHIPS} >8-12mm = 39.95% and M_{CHIPS} >12-16mm=29.93 %) at machine productivity of 1.40 Mg/h and energy requirement of about 12.35 kW.h/Mg.

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الملخص العربي

تصنيع وتقييم أداء نموذج أولي لآلة تقطيع الأخشاب لإنتاج الرقائق المصغرة

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بإستخدام آلة تقطيع الأخشاب القرصية التقليدية فإن الأحجام الكبيرة لرقائق الخشب تظل حاضرة حتي في حالة ضبط تشغيل الآلة بغرض إنتاج الرقائق المصغرة و التي تعتبر غير مناسبة لبعض التطبيقات و التي تحتاج إلي أحجام صغيرة من هذة الرقائق مثل مصبعات الكتلة الحيوية أو حتي فرشة الدواجن و ذلك علي سبيل المثال، ومن هنا فإن هناك حاجة ماسة لإنتاج رقائق الأخشاب المصغرة لتكون متوافرة لنطاق واسع من الاستخدامات داخل المزرعة. لهذا الغرض فإن هذة الدراسة تهدف إلي تصنيع و تقييم أداء نموذج أولي لآلة محلية الصنع لتقطيع الأخشاب إلي رقائق من خلال تزويد قرص التقطيع التقليدي بمجرشة ذات مطارق متأرجحة خلف القرص مباشرة علي نفس عمود الدوران وذلك مع إستخدام متبقيات تقليم أشجار المانجو لإنتاج رقائق الأخشاب المصغرة بأعلي جودة (رقائق منتظمة الشكل وأقل فاقد من الرقائق المسحوقة) وبأقل طاقة مستهلكة. تم تقييم أداء الآلة تحت متغيرات تشغيل تشمل ثلاث سرعات دورانية لقرص القطع و هي٧٥٠، ١٠٠٠، ١٢٥٠ لفة/دقيقة و التي تناظر سرعات محيطية ١٧,٦٦ ،٢٣,٥٥، ٢٩,٤٣ م/ث علي الترتيب و وثلاث زوايا للقطع ٤٨°، ٥٠°،٥٤°، ٥٨° وثلاث أقطار لغربال صدر المجرشة وهي ١٢، ١٦، ٢٠ مم ، علماً بأن السرعة الدورانية للمطارق هي نفس سرعة قرص التقطيع. تم تقييم الآلة مع الأخذ في الأعتبار إنتاجية الآلة و توزيع أطوال رقائق الخشب المصغرة و الطاقة النوعية المستهلكة في عملية القطع و التصغير. وقد أشارت النتائج إلي أنه من الموصي به إستخدام الآلة عند سرعة دورانية لقرص التقطيع مقدارها ١٠٠٠ لفة/دقيقة (٢٣,٥٥ م/ث) وزاوية قطع للسكينة (زاوية إختراق)٥٨° و قطر غربال صدر المجرشة وهي ١٦مم لتحقيق أفضل توزيع لأطوال رقائق الخشب المصغرة و التي يتمثل في ≥٣مم=٦,٠٥%، >٣-٨ مم=٢٤,٠٧ %، >٨-١٢مم=٣٩,٩٥%، >١٢-١٦ مم= ٢٩,٩٣% و التي حققت أقل نسبة للدقيقة (الناعمة) وذلك عند سعة إنتاجية للآلة مقدارها ١,٤٠ ميجاجرام/ساعة و طاقة مستهلكة ١٢,٣٥ كيلووات.ساعة/ميجا جرام.

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