

INFLUENCE OF DRUM CHIPPER SETTING ON THE WOOD CHIPS PERFORMANCE

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ABSTRACT

Recently, spread in the world many different categories of wood chipper to be convert the field trees waste to chips. In Egypt, especially in the new land farms the wastes of field trees represent an immense problem. For this reason, the wood chipper machine manufactured in small workshops scattered in the region of Dakahlia governorate. Because of the owners of these workshops, do not have experience in the design of wood chipper machines. Therefore, it immediately needed to evaluate each of the chipper design and its operation. Therefore, the aim of recent paper are to evaluate the design of offset slider crank for drum wood chipper and to evaluate operating parameter of drum chipper on wood chip removal rate (WCRR, m³/h), actual chip thickness (ACT), share plan angle (SPA), chip thickness ratio (CTR), chip reduction coefficient (CRC), size classification of wood chips (SCC) and the machine productivity. The operating parameters of the local chipper machine (model MUPM) included two wood sit positions in chipper (perpendicular of wood fiber relative to cutting drum (Per) and parallel to wood fiber (P); two cutting drum revolution (Per1=5000 rpm and Per2= 5500 rpm) two types of wood (white wood or exported and local wood or feedstock) and two moisture content (17% for white wood and 33% for feedstock).

Key words: *chipper machine- wood chips- cutting angle- chip thickness- size classification of wood chips*

INTRODUCTION

In Egypt, there are no clear statistics or documented data on the volume of waste field trees or green waste, but in recent times it represents a real problem. On the other hand and at the local level, increased demand for the utilization wood chip as good bed for the animals bedding or use as source of renewable energy. Consequently, it led to increase the requests on wood chipper equipments.

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Generally, there are several types of chipping machines relative to the cutting principles currently in use. Mainly are; disc chipper, twin disc chipper, v-drum hop chipper, v-drum, hog chipper and cylinder drum chipper. On the other hand, Toenshoff and Denkena (2013) reported that, depending on the work-piece material and the cutting conditions, the following mechanisms of chip formation can be distinguished as continuous, lamellar, segmented and discontinuous chips formation (figure 1). Different methods of cutting have been employed in the wood products industry depending on the use of the wood and purpose of operation (Sutherland and DeVor -1986). In all of these cutting methods, the quality of surface obtained because of the process affected by factors related to the processed material (tree species, quality and moisture contents of materials, etc.). Operating parameters such as different angles affect the wood chip removal rate. The clearance angle controls the pulling of the logs towards the chipper plate (Uhmeier-1995), and consequently, the chip size distribution. The clearance angle also affects the resulting chip thickness rate (Zmitrowicz-2006). The knife angle used is normally between 30° and 37° . Kajberg and Wikman (2007) and Bergander and Salmén (2000) showed that a decrease in the knife angle from 40° to 30° reduces the chip thickness, the cutting force and chip damage.

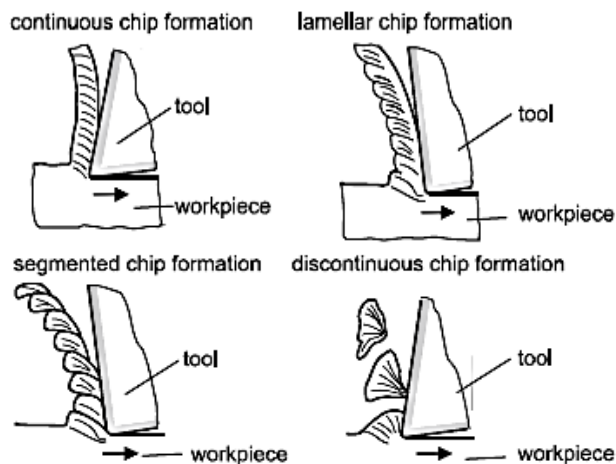


Fig. (1) Mechanisms of chip formation (Author, Bergander and Salmén -2000)

Jernkvist and Thuvander (2001) identified that there are at least two chip formation processes i.e. an opening mode and a forward shear mode. The 20° and 30° knife angle produced chips by opening. The 40° knife angle formed chips by forward shearing in a small percentage of cases and the 50° knife angle formed chips by forward shearing in most instances. The performance of a cutting tool or the machine ability of a work material can be evaluated by measuring the chip reduction coefficient. There is difference in the chip reduction coefficient for parallel, and perpendicular to the fiber axis. Several models have been simulated to study parameters/factors that influence the chip reduction coefficient [Gonçalves and Néri (2005); Wen-Hsiang Lai (2000); Tlustý (1991) and Kline et al. (1982)]. These parameters include; number of cutter knife, cutting angle, bluntness of cutters, etc. and other factors related to; the machinery technological level, feeding rate, cutting speed, etc. (Toenshoff and Denkena-2013).

The common construction of wood chipper machines that can produce wood chips are; the cone-screw wood chipper and the drum or the disc chippers. Operators stated that disc chippers produce more uniform chips than drum chippers, especially if fed with good quality raw material. In contrast, flexible small branches may pass through the disc slots uncomminuted, resulting in low chip quality. For this reason, operators believe that drum chippers are the best when dealing with small-size feedstock, such as tops and branches (Svensson-2007). Therefore, many attempts were carried out to improve the drum chipper. One of them, is investigated offset slider mechanism which the power supply to drum chipper almost, directly through bully and flywheel and on other design indirectly by slider mechanism (Ismail-2004).

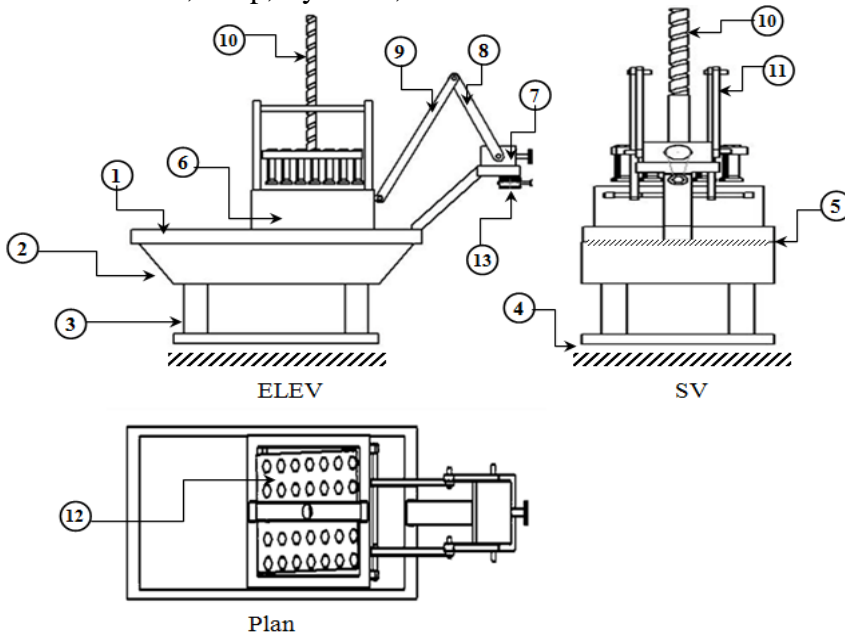
The offset slider mechanism is constructed by the Egyptian workshop owners and because of the owners of workshop have low experience about the design of such machine and these machine also facing some problems when you running in the domestic market. Therefore, it requires re-evaluating of such equipment design. Consequently, the aim of recent paper are to evaluate the design of offset slider crank for drum wood

chipper theoretically and practically, to evaluate operating parameters of drum chipper on wood chip removal rate (SRR), chip thickness ratio (CTR), chip reduction coefficient (CRC), size classification of wood chips (SCC) and the machine productivity.

MATERIAL AND METHODS

Wood chipper machine

The common construction of wood chipper machine was constructed in small workshop at Dahlia governorate and was re-design at workshop of agricultural engineering-Mansoura University. The general via of wood chipper machine local model MUPM as shown in Fig. (2), consists of two principal parts. The first is power supply unit that including the offset slider mechanism, hoop, flywheel, chains and belts.



- 1- Frame
- 2- Chips container
- 3- Iron legs
- 4- Base
- 5- Rod
- 6- Slider wood box
- 7- Worm gear
- 8- Connected rod
- 9- Coupler
- 10- Vertical spinner shaft
- 11- Sliding guide
- 12- Bolt with helical spring
- 13- Offset slider mechanism motor

Figure (2): Layout of investigated offset slider chipper machine

The second is the chipper unit, that containing drum, slider box of wood and chips container. The two units were established on the main frame

with dimensions of 1900×800×900 mm length, width and height respectively. It made from iron with U section of 75×75×3mm. Four iron legs with U section of 100×100×5 mm were welded with the lower surface of the container that storing the chips output from a process operation of the chipper. The basic dimensions of offset slider mechanism after modification are illustrated in Fig. 3. It driven with electrical motor of 7.0 kW with 2990 rpm. The motor motion travel to two crank arm of offset slider mechanism by worm gear with reduction of 1:7. At rotating the crank arm, the motion conveying to the cobbler that bolted with slider box.

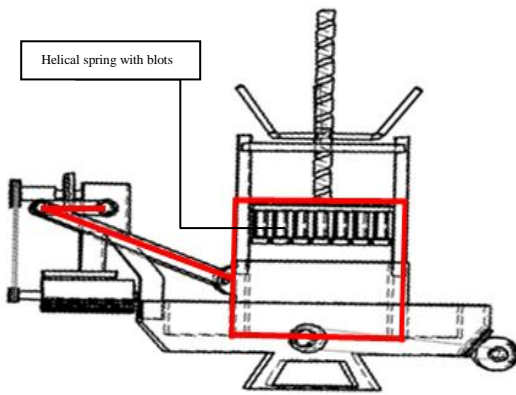


Figure (3): Offset slider mechanism and slide box specification



Figure (4): Share of chipper drum

The principal part of second unit is chipper drum. It is made of a closed drum equipped with blades, as long as the whole drum axis, a counter-blade and an interchangeable output-sieving grid for chips calibration. The closed drum made from steel iron with diameter of 100 mm and 800 mm length. It fixed by two-roller thrust bearing on the main frame under the surface of slider box and near from the end side of it. A longitudinal gab on the drum surface is constructed and inside the gab, the sharp share thickness shown in figure 4 is constant and equal 1.86 mm.

The drum of chipper connected with transmutation system that takes the rotation from electrical motor with 5.5 kW and 1440 rpm. The slide box dimension is 800×700×500 mm long, width and height. It was from iron

sheet with 5 mm thickness. To reduce the friction forces and keep the slider box motion easy it laying on two-rod bar. The top surface of slider box covered with rectangle plate with 10 mm thickens. This plate moving up and down through the four guides by spinner and nut (handedly system). Numbers of helical spring with guides were distributed on the lower surface of plate to keep the force between the woods and chipper drum constant (figure 3).

Experimental condition

Two major of studies are identified. Theoretically, to determine the dimensions of offset slider mechanism and re-designed it to avoid the machine disadvantages like supplementary vibration and high noise. Practically, the indoor experiment conducted to evaluate the now designed.

Theoretical consideration

It is including two shares. One relative to offset slider-crank motion and the other relative to the drum share operation.

The fundamental operating theory offset slider-crank motion

Referring to the mechanism system that transmit the motion from the center of worm gears (in put motion) to the slide chips box (out let motion) as shown in figure (3), it easy to see that, the motion is movement sliding by four-bar system and take the form of offset slider crank. From principles basic, this style of movement able to conform the chipper stroke in times bigger than that return stroke. In addition, by referring to the basic guideline principles of the machines theory to achieve this requirement must be:

- Recall that an offset slider-crank has quick return action.
- Must determine the required Q (Time ratio) and β (Imbalance angle) where time ratio equal time of advance stroke per time of return stroke.
- To produce smooth acceleration must be $L_3(\text{coupler length}) \gg L_2$ (crank length)
- Coupler ratio equal (coupler length (L_3) / crank length (L_2)) and must be > 4 . Then the coupler length must be more than that fourth times of crank length and in normal case may be equal 6 crank time

Regarding to the dimension of offset slider crank for machine chipper before modified, the input link 2 (L_2) is rotating at a constant angular velocity with length of 350mm, the offset distance (L_1) is 360mm and coupler length (L_3) of 1120mm. Then, the angle of crank (θ_1), when the slider is at the left-most position is equal to 152.13 degree (calculated according to David -2012 and regarding to figure 5). In addition, the crank angle (θ_2) when the slider is at the right-most position = 345.82 degree. Then, represents the stroke length is 744.5mm and the time ratio is 1.16.

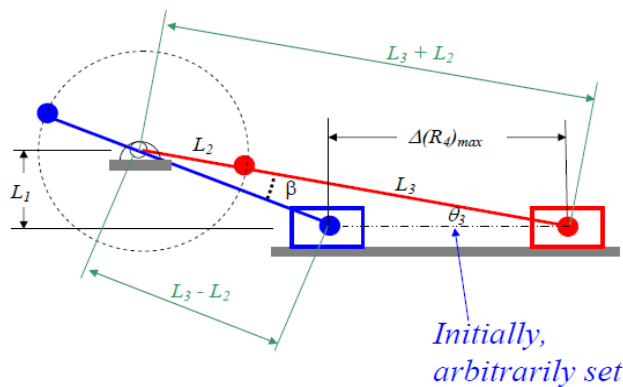


Figure (5): Offset slider-crank mechanism

Also, the displacement respect to time in seconds for the slider unit (container of supply wood to drum chipper) as shown in figure (6) indicates some imperfection such as: the time ratio is very low, the stability of machine is very little and the velocity and acceleration diagram is unharmonious.

So, it's investigated a simple program to determine the optimum dimension to overcome above deficiency. From the investigated program, the dimension of offset slider crank for machine chipper are $L_1 = 400$ mm; $L_2 = 250$ mm and $L_3 = 1120$ mm, then the $\theta_1 = 148.24$ degree; $\theta_2 = 344.21$ degree and the time ratio = 1.95. The relationship between time and each of displacement, velocity and acceleration diagrams illustrates in figure (7). From diagrams in figure, the motion of slide crank is very state and homogenous relation.

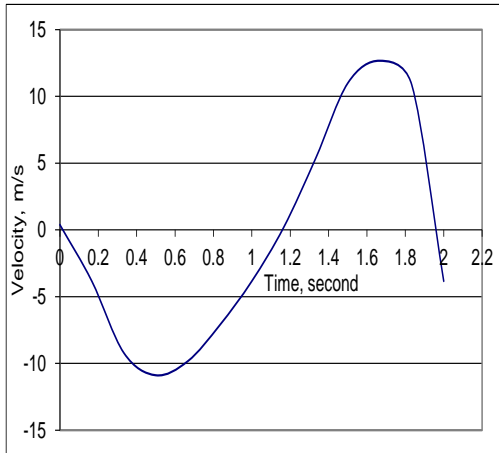


Figure (6): Displacement diagrams for the slider before modified

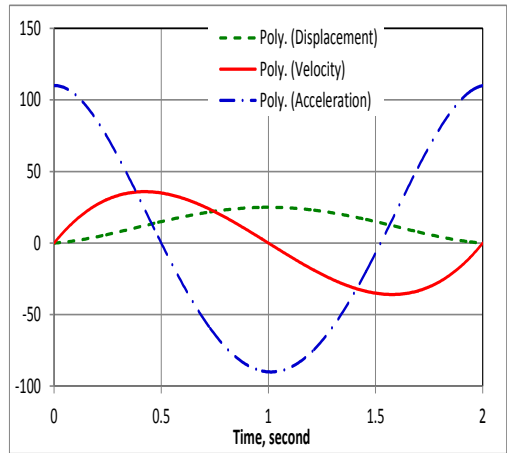


Figure (7): Displacement velocity and acceleration diagrams after modified

Drum-Share operation

Concerning to the simulation work of wood chip machine, that obtainable in the Department of Agricultural Engineering after modified, the cutting device unit of wood is subject to the system of orthogonal cutting model (OCM). As shown in figure (8), the share tool is inclined with rake angle (α = shear rack angle) and cutting angle (ϕ = shear plane angle).

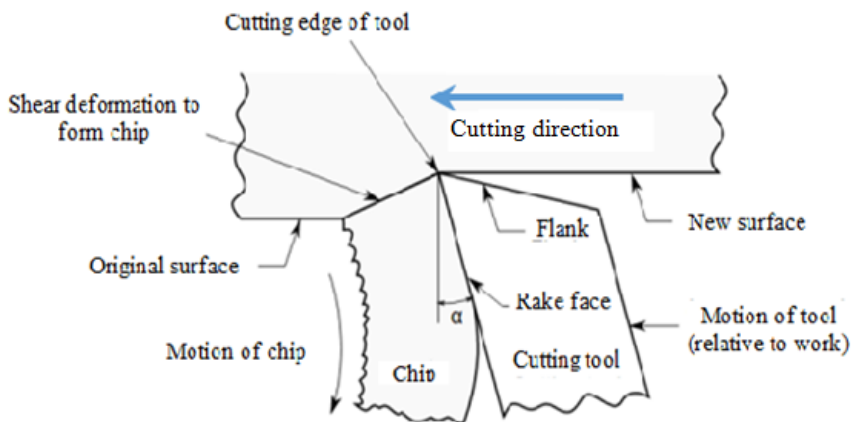


Figure (8): The orthogonal cutting system rack (α) angles

The chip plan angle (ϕ) was identified as " $\tan \phi = r \cos \alpha / (1 - \sin \alpha)$ " sited from David (2012). Where; (α) is share rake angle, and (r) is the

chip thickness ratio (CTR). The identification of CTR is the relation between “ t_0 ” (thickness of the chip prior) to “ t_c ” (chip thickness after separation) as $CTR = t_o / t_c$. From the primary experiments allows notes that (t_c) chip thickness after cut is always greater than before, so chip ratio is always less than 1.0. This result comes to an agreement with Kajberg and Wikman (2007) and Thuvander, et al. (2000).

The indoor experiment conditions

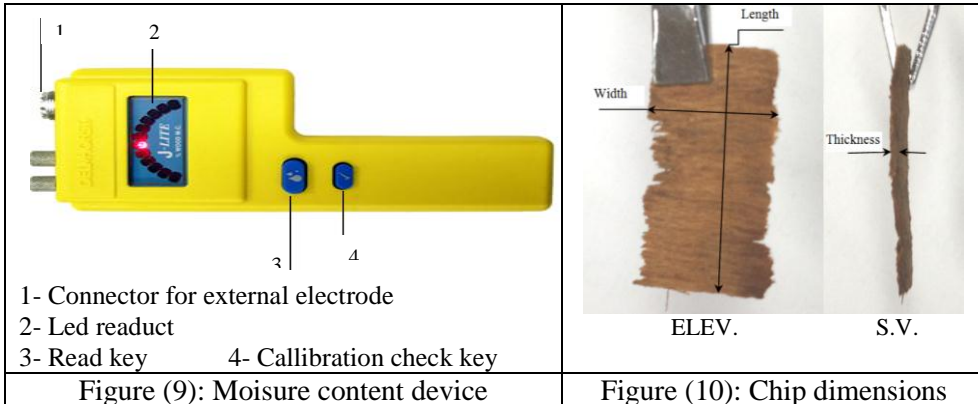
The tests were conducted in March 2015 at the wood feedstock that scattered from Mansoura University Garden and the residual from wood workshop. The wood chipper machine alternately fed with two different feedstock types: white wood residual (imported) and garden wood residual (feedstock- local). All feedstock were fresh and came in pieces with an approximate length of 70cm. The average moisture content ranged in-between 20 and 46% for local wood (feedstock) and for the imported of below 20%. The feedstock were chosen because they are widely available and often easy used for chip production.

The moisture content for two woods under experiment were quickly recorded using a J-Lite wood moisture content. It recognized worldwide as the most accurate method for measuring moisture with moisture range from 6 to 30%. It built-in calibration checks with 9V battery as shown in figure (9).

The main chips dimensions (thickness, wide and length) were measured by taking as samples from each repetition for all variables under experiments and using electrical caliper model 16 ES with accuracy of 0.01mm (figure-4).

Wood chips removal rate under all variables were evaluated by weighing all wood chips produced within each repetition per unit time.

Particle size distribution, according to European Standard CEN/TS 15149-1 four sieves were used to separate the following chip classes: >20 mm, 20–50 mm, 50–100 mm. Each fraction was then weighed with a precision scale (figure-10).



Data were analyzed with the Excel statistics software. In particular, the software was used for performing a typical analysis of variance (ANOVA), especially suited to the factorial experiment just described. Analysis of variance was conducted to determine the most parameters affecting chips variation. In addition, the relationship between productivity, piece size and tree part was estimated using multiple linear regression technique.

RESULTS AND DISCUSSION

Wood chips removal rate (WCRR, m³/h)

The relationship between the cutting depth of drum knife and the amount of wood chips removal rate (WCRR) illustrated in figure (11) under different cutting drum revolution (5000; 5500 and 6000 rpm). Generally, the above relationship was found as directly proportional function. It mean that increasing the cutting depth increased the WCRR, but the rate of increasing is higher for 6000 rpm drum revolution by about of 1.2 than at 5000 rpm under cutting depth of 2 mm. However, there were 1.25 and 1.42 times at 3.0 and 4.0 mm share cutting depth. This is due to the wood specifications on experimentation is not matching. Under the specification required for product wood chips with thickness of 2 mm, then the amount of chips removal rate were 1.08; 1.13 and 1.30 m³/h at cutting speed of 5000; 5500 and 6000 rpm respectively.

Actual chips thickness

The setting angle of share knife is the major parameters affecting the actual chips thickness (Ismail -2009). Figure (12-A) shows the

relationship between share setting angle and the actual wood chips thickness. The above figure indicated that at increasing the share-setting angle from 20 to 30 degree, the actual chips thickness increased. For example at 20; 22; 26 and 30 degrees of share setting angle, the average of chips thickness recorded 0.16; 0.19; 0.22 and 0.28mm respectively.

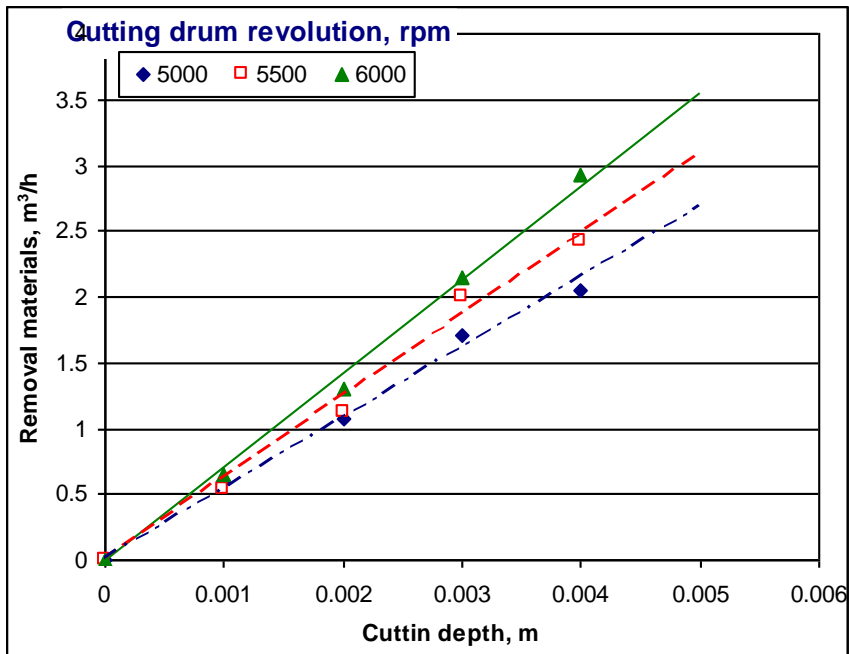


Figure (11): The cutting drum speed versus amount of chip removal rate

Share plan angle (degree)

The analysis was conducted to determine the effect of share plan angle on the chips thickness. The results of above relation illustrates in figure (12-B). Generally, by ascending share plan angle descending the chips thickness this results agreement with Ismail and Abou Habaga (2008). To regulate the cutting share with the share plan angles needed to flow this steps; for example at 0.2mm chips thickness will be found at seating angle of 23 degree and 50 degree share plan angle.

Chips thickness ratio (CTR)

Because of the major factors affecting power consumption of drum chipper machine is the values of cutting force which is depending of the cutting depth that consider as function on wood chips thickness not chips

length or width. Then the wood thickness consider as the main parameters which the study identification. The relation between cutting depth and the actual chips thickness is consider the chips thickness ratio (CTR). Figure (13) illustrates the relationship between the actual chips thickness and the CTR at different share setting angle. Generally, from figure the results related that the CTR is direct preoperational with each of chips thickness and setting angle.

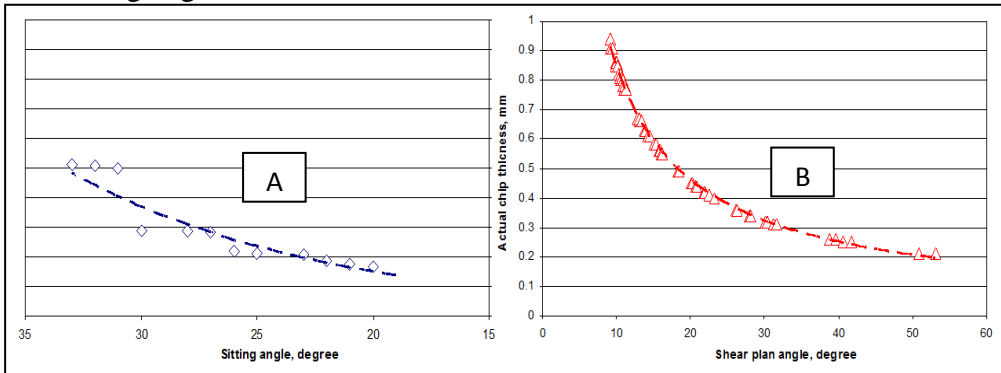


Figure (12): Actual chips thickness as function for sitting angle and share plan angle

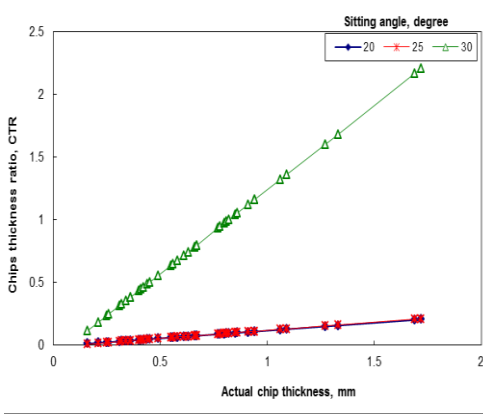


Figure (13): The relationship between the actual chips thickness and the CTR

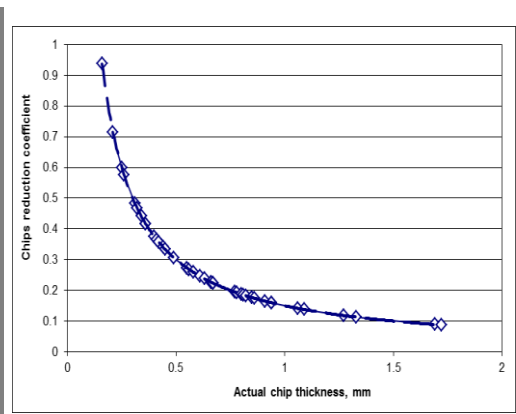


Figure (14): The actual chips thickness via the CRC

Chip reduction coefficient (CRC)

Figure (14) conducts the function of actual chips thickness and the chip reduction coefficient. The above relation is inversely functioning. By increasing the actual chips thickness the CRC decreased for all treatment under study and it non-significant different. The same trend was found for

the relationship between the share-setting angle (StA) and chap reduction coefficient (CRC). At actual chips thickness range from 0.25 to 0.5 the CRC is rapidly decreased and it very slowly decreased at chips thickness more than 0.5mm.

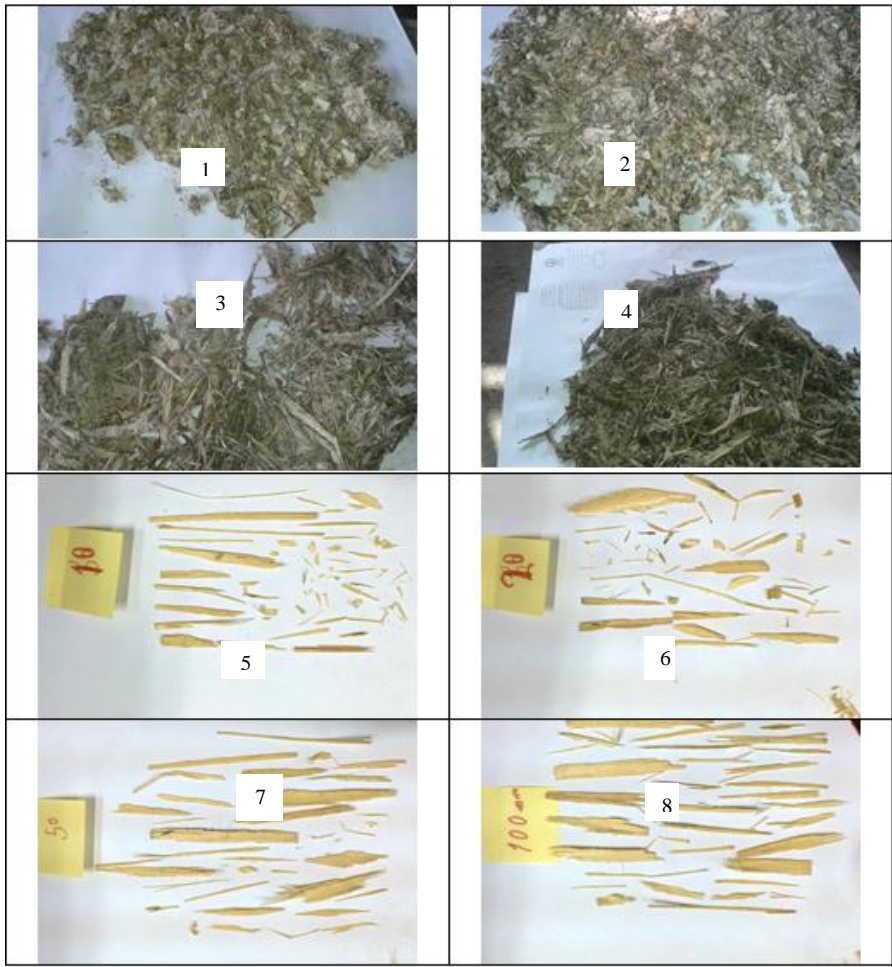
Size classification of wood chips

The second part of experiment is evaluate the product of machine by identifies the size classification of wood chips (SCC). It evaluates under two wood sit positions in chipper-box (perpendicular of wood fiber relative to cutting drum (Per) and parallel to wood fiber (P); two cutting drum revolution (Per1 = 5000 rpm and Per2 = 5500 rpm) two types of wood (white wood or exported and local wood or feedstock) and two moisture content (17% for white wood and 33% for local wood). Three methods were conducted to evaluate SCC as show in figure (15). From figure and by hand touch, it easy to notes that, the photos "1" and "2" is more softly than that for "3" and "4" and vice versa for "5"; "6"; "7" and "8". Also, the smallest chips pieces found at variables in photo "2". Furthermore, the largest wood chips dimensions were found over the sieves with much of 10 mm at variables in photo 5 than that in variables at photos "6"; "7" and "8".

The frequency functions

The frequency of main dimension (thickness – width - length) for wood chips under different variable illustrates in figure (16). Mostly, the above relationship in frequency curves represents the right side of the normal distribution curve except at variables of local wood moisture content of 17%, the cutting wood perpendicular on wood fiber and at measuring the thickness and width for wood chips.

Frequently, from figure, the peak frequency for wood chips thickness, width and length recorded at fields of (1-6mm); (3-14mm) and (3-33mm) respectively for white wood. However, there were (0-3.5mm); (1-6mm) and (3-20mm) respectively for tree woods. It means that the chips dimension for white woods is height than that for tree woods.



1- L.W , M1, Par1,V1 2- L. W M1Par2,V2 3-l. W M1, P. V1 4-L.W M1, P, V2
 5- Ex.W , M2, Par1,V1 6- Ex. W M2Par2,V2 7-Ex. W M2, P. V1 8-Ex.W M2, P, V2

Figure (15): The photographic of chip out from chipper machine

On the other hand, at measuring chips width parameter and under P; Per1 and Per2 variables, there are not differences effects. At middle category 6 mm the frequency recorded 20%; 19.355% and 12.5% respectively for white woods. But, there were 40%; 44% and 45% for tree wood and at middle category of 1.25 mm. Referring to chips length, there were highest different between P; Per1 and Per2 variables. In addition, there were highest differences between white and tree woods. The Per2 parameter recorded the best frequency with the lowest category range.

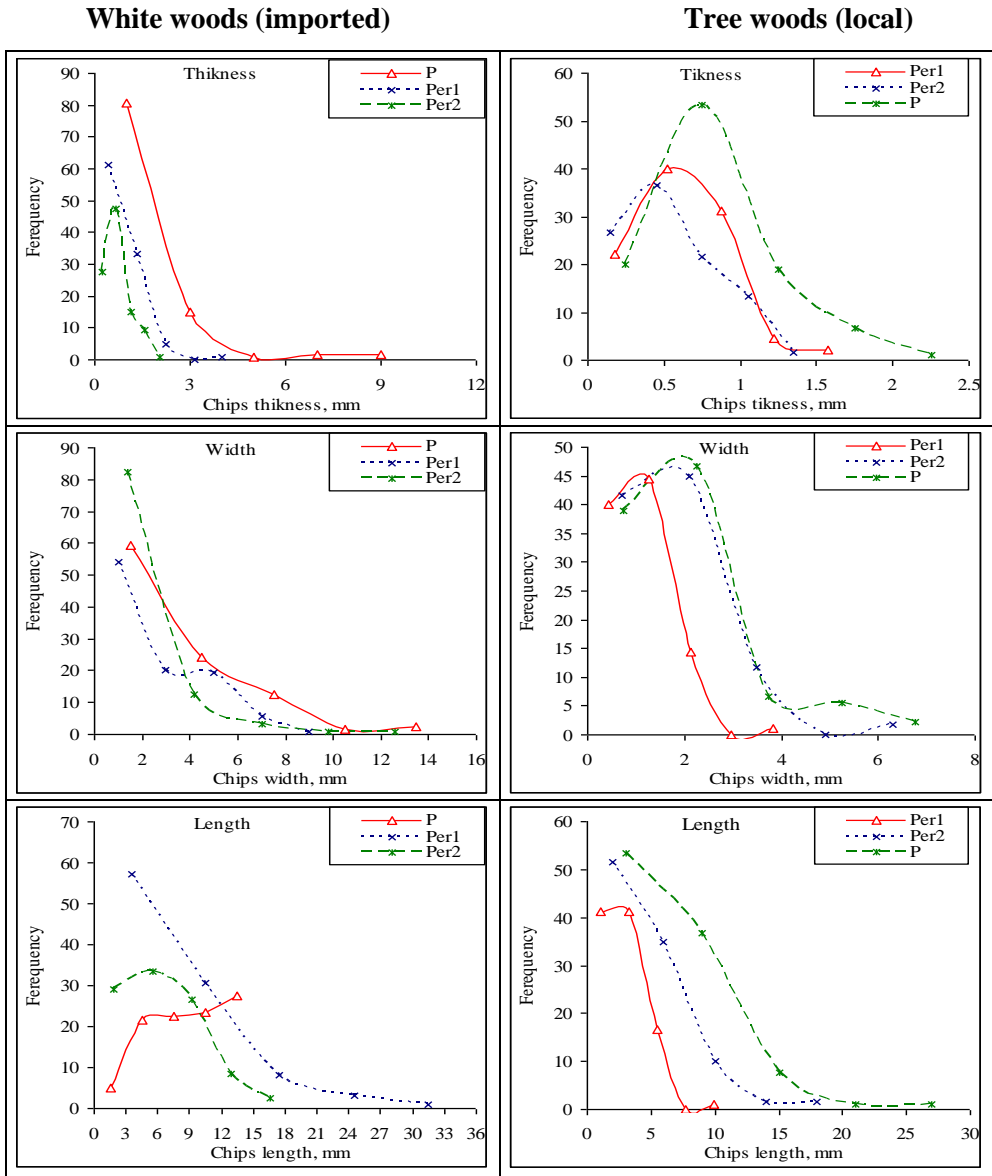


Figure (16): The frequency curves for wood chips distribution

Average chips dimension

Figure (17) indicated the average chips dimension over the sieves under different variables (P; Per1 and Per2) for two woods types. From figure, clarify the amount of average chips dimension (Th; W and L) increased for sieves with mesh of 20, 50 and 100mm for white wood but for local wood the above relation is gradually increased.

White woods (imported)

Tree woods (local)

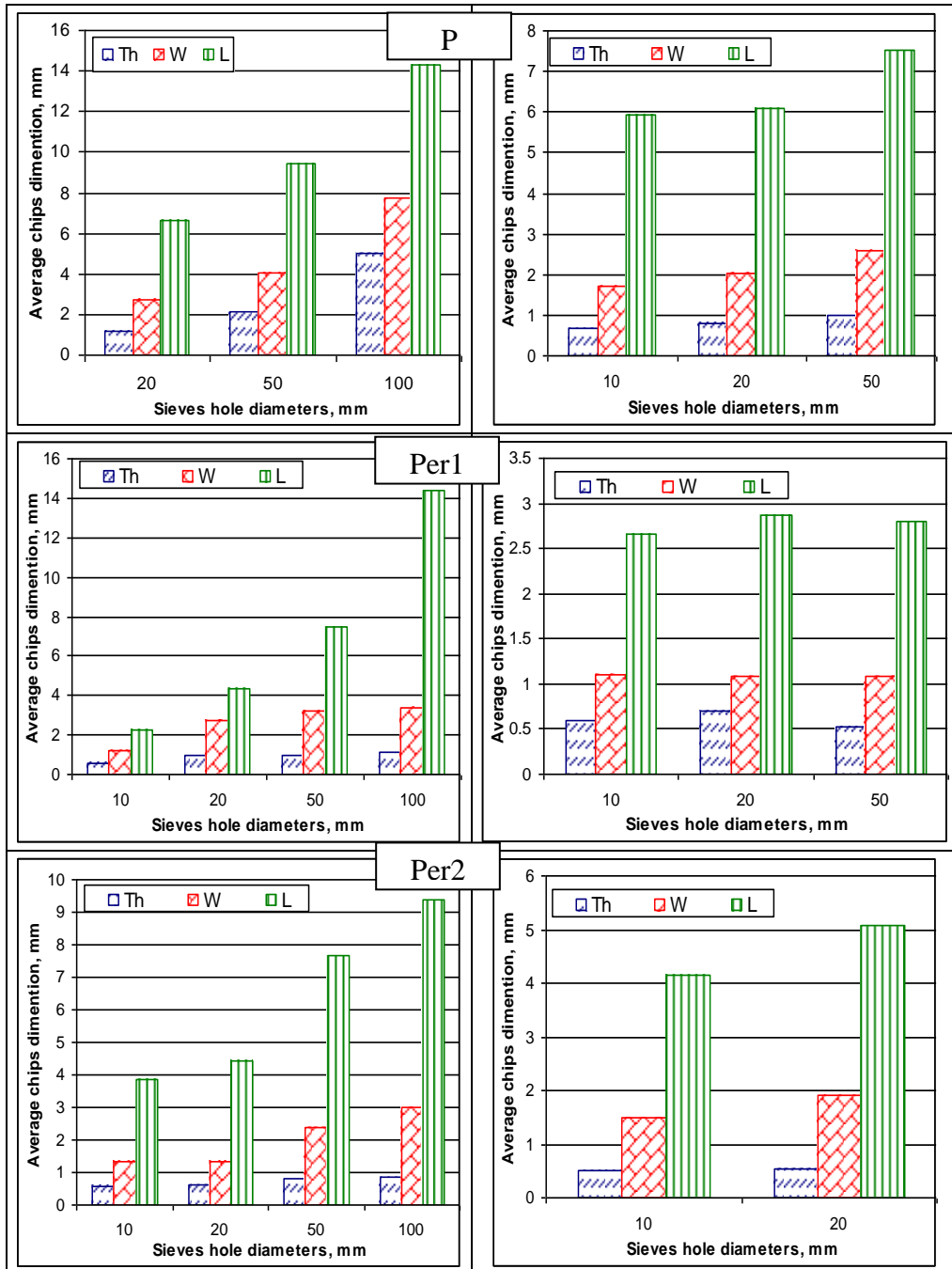


Figure (17): Average chips dimension curves for wood chips variables

The average chips thickness (Th) recorded 1.15; 2.15 and 5.05mm at mesh of 20, 50 and 100mm respectively for white wood and “P” variables against 0.6; 0.7 and 0.5mm for local woods and under the same variables. The best results were found at Per2 for local wood that “Th” recorded (0.5 and 0.54mm) and “W” verified (1.49 and 1.90 mm) and “L” noted (4.2 and 5.08mm) at sieves with mesh of 20, 50mm respectively. Table (1) represents the stander deviation of chip dimension above the sieves under different variables (P; Per1 and Per2) for two woods types. The variation of SD is very low and nearly equal (from 0.321 to 5.880) for local wood under all treatment. However, for white wood is wide deviation from 0.29 to17.81.

Table (1): The stander deviation for average chips dimension

Variable	Sieves diameter, mm	White			Local		
		Per1	Per2	P	Per1	Per2	P
Thickness	10	1.706	0.296	-----	0.321	0.272	0.252
	20	3.503	0.430	0.370	0.313	0.291	0.383
	50	8.842	0.568	0.370	0.224	-----	0.523
	100	17.81	0.607	2.00	-----	-----	-----
Width	10	1.683	0.917	-----	0.568	1.028	0.929
	20	3.451	1.918	0.370	0.441	0.853	1.370
	50	8.692	2.124	0.370	0.726	-----	1.320
	100	17.634	1.825	2.00	-----	-----	-----
Length	10	2.402	1.116	-----	1.183	2.852	5.880
	20	3.580	2.099	3.132	1.475	3.513	3.267
	50	8.139	2.615	2.907	1.864	-----	3.405
	100	16.755	6.051	2.161	----	----	-----

Chips rate dimension (CRD, %)

The average values of the chips size distribution can be seen in figure (18) for white and local woods. Increasing the Per1 to Per2 variables leads to an increase in chip size for both white and local woods.

The percentage of the size class (>10 mm) rises from 16.4 to 20.0% for chips thickness (Th) while the percentage of the size classes (50 and 100 mm) decreases with great drum cutting revolutions. The variation in size distribution is linear with increasing cutting drum revolution, meaning that the greatest percentage of the class size (>10) will be produced at Per2.

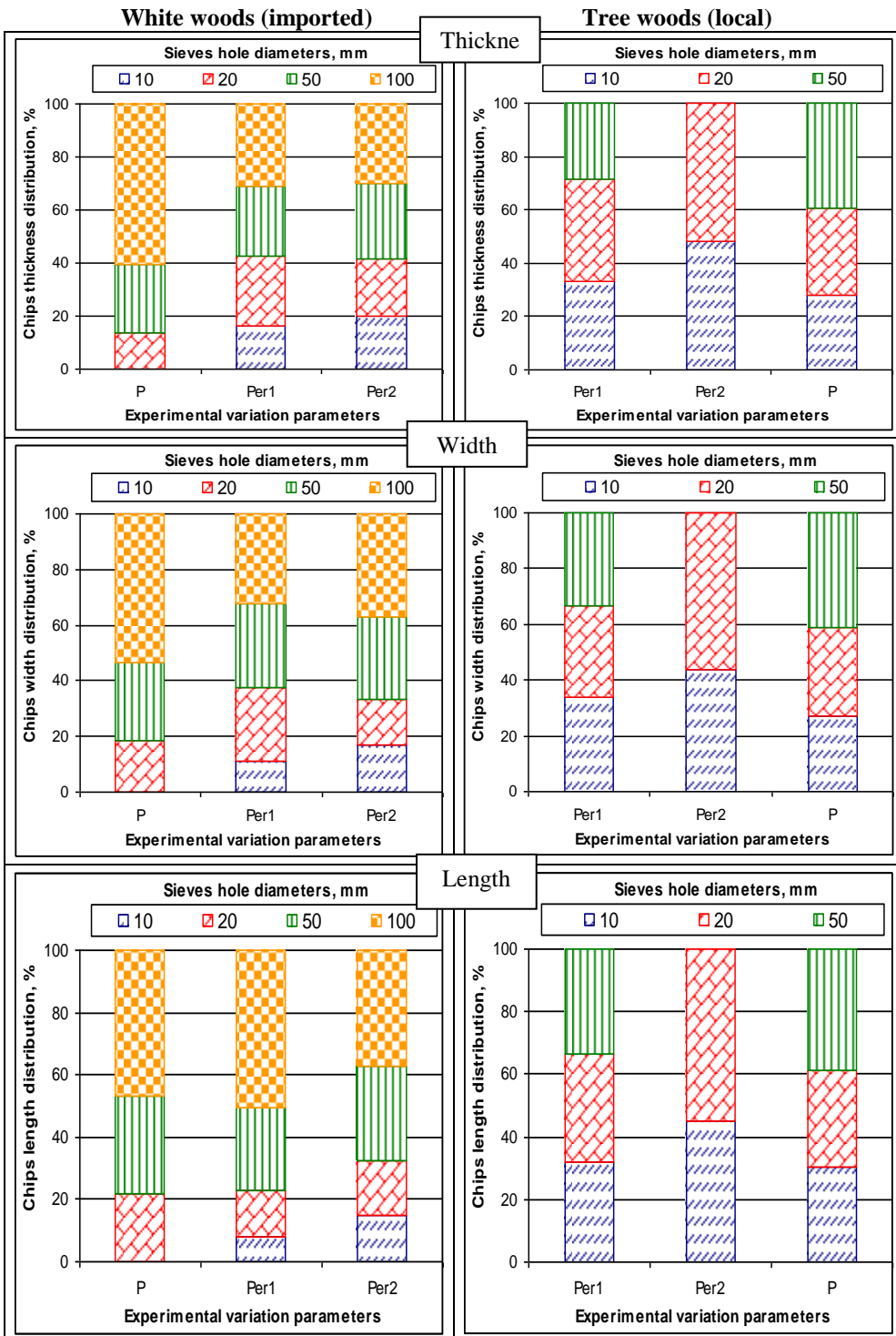


Figure (18): Chips rate dimension curves for wood chips variables

The chipper wood machine productivity

The productivity of offset slide crank chipper wood machine (local model MUPM) was evaluated under two types of wood (local and white woods), different cutting depth and three levels of cutting drum revolution (rpm). Also, the wood moisture content for two woods types were nearly equal to 17% (exported wood) and blow or equal 33% (for local wood). The above functions were created as shown in figure (19).

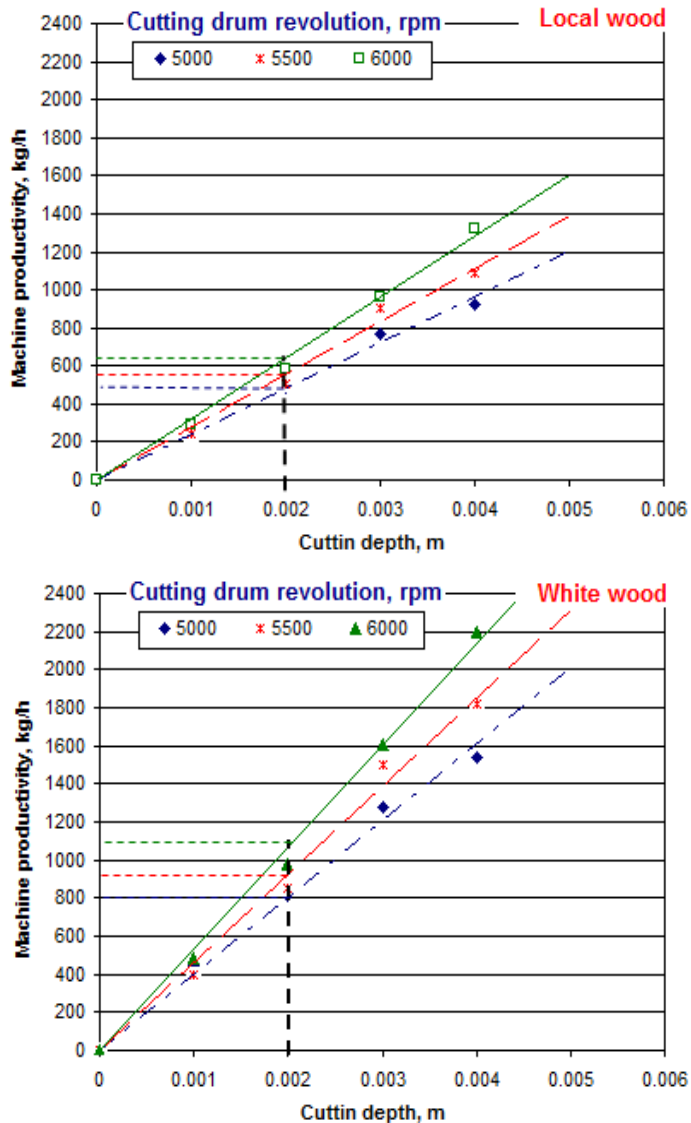


Figure (19): The wood chips productivity via cutting depth for two wood types

Generally, increasing each of cutting depth and cutting drum revolution increasing the wood chips productivity. For example, at cutting depth of 2.0 mm and using the white woods, the chips production were 395.64; 435.2 and 474.76 kg/h at 5000; 5500 and 6000 cutting drum revolution. The same trend was found at using local wood material. The wood chips productivity were 237.38; 261.12 and 284.86 kg/h at 5000; 5500 and 6000rpm cutting drum revolution. From above results, the machine chips productivity vary depending on the type of wood, as well as different operating parameters such as cutting depth and drum revolution.

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الملخص العربي

مواصفات إنتاج رقائق الخشب كنتيجة لوضع درفيل التقطيع

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في الآونة الأخيرة انتشر في العالم العديد من معدات تجهيز مخلفات الأشجار الحقلية وتحولها الي قطع صغيرة. ونظراً لاتساع الأراضي الزراعية في مصر وخاصة في الأراضي الجديدة والتي تحتاج إلى سياج من الأشجار حولها لذا يشكل التخلص من تلك الأشجار في مراحل نهاية العمر أو عند التقليم مشكلة هامة حيث تبلغ مخلفات تلك الأشجار ما يقرب من ٣٢% من جملة المخلفات مما ادي الي انتشار وتصنيع معدات خاصة بنقطيعها في الورش الصغيرة المنتشرة في محافظات عدة وأهمها محافظة الدقهلية. ولان أصحاب تلك الورش لا تمتلك من الخبرة في مجال تصميم المعدات لذلك كانت الحاجة ماسة لتقييم وإعادة تصميم وتشغيل تلك المعدات. من جهة اخري ارتفع الطلب على استخدام نشارة الأشجار في كثير من الأغراض مما دفع الورش الي تصنيع تلك المعدات بكثرة لإنتاج رقائق الخشب. لذلك يعتبر الهدف الأساسي لهذا البحث تقييم مجالين أساسيين أولهما إعادة تصميم الحركة الميكانيكية العكسية لزراع المكبس باستخدام برنامج اكسيل بسيط حيث كانت أفضل النتائج لهذا التصميم على النحو التالي: إزاحة صندوق الخشب ٧٦٠ مم، البعد من مركز دوران عمود الكرنك ونقطة الاتصال بخزان الخشب ١١٢٠ مم، طول ذراع عمود المرفق ٢٥٠ مم وسجلت زاوية إزاحة قطع الخشب ١٤٨.٢٤ درجة وان النسبة بين زمن الازاحة وزمن العودة ١.٩٥ (Time ratio) والمسافة الرأسية من مركز عمود الكرنك لمستوي انزلاق خزان الخشب ٤٠٠ مم.

والتقييم الثاني يشمل دراسة خصائص رقائق الخشب المنتجة بواسطة المعدة وذلك عن طريق قياس سمك رقائق الخشب (Chips Thickness ratio) والتقييم الحجمي للرقائق المنتجة وتقييم الإنتاجية.

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