DEVELOPMENT OF A NEW-INVENTED SYSTEM FOR TREE-BRANCHES CHOPPING

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ABSTRACT

The aim of this research is to develop, construct and evaluate a new-invented system for tree-branches chopping. The chopping system consists of frame, tires, draw-bar, 15-kW electrical motor, feeding, cutting, chopping units and suction-fan. The main results in this study can be summarized in the following points:

- The maximum average of chopping length of 19 mm was obtained by using chopping-knives speed of 900 rpm (27.31 m/s), concave-hole diameter of 20 mm and tree-branch diameter of 50 mm. Meanwhile, the minimum average of chopping length of 6 mm was obtained by using chopping-knives speed of 1200 rpm (36.92 m/s), concave-hole diameter of 14 mm and tree-branch diameter of 20 mm (at constant clearance of 5 mm, moisture-content of 10 %, cutting-knives speed of 450 rpm and feeding-drums speed of 10 rpm).
- The minimum productivity of 238 kg/h was obtained by using chopping-knives speed of 900 rpm (27.31 m/s), concave-hole diameter of 14 mm and tree-branch diameter of 50 mm. Meanwhile, the maximum machine productivity of 667 kg/h was obtained by using chopping-knives speed of 1200 rpm (36.92 m/s), concave-hole diameter of 20 mm and tree-branch diameter of 20 mm (at constant clearance of 5 mm, moisture-content of 10 %, cutting-knives speed of 450 rpm and feeding-drums speed of 10 rpm).
- The operation and production costs at chopping-knives speed of 1200 rpm (36.92 m/s) were 17.42 – 18.71 L. E./h and 28.01 – 68.98 L.E./ton for all tested tree-branch and concave-hole diameters.

This study is a part of outcomes from Ph.D. Thesis.

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INTRODUCTION

The agricultural crop residues epically horticultural are considered one of the most important problems that face the environmental life and farmers in Egypt. The mechanical treatment (cutting or chopping and briquetting processes) is the primary step and suitable solution for solving this problem.

The first step towards solving this problem is to cut, crush and mill these lignocelluloses materials in order to be used as raw materials in several processes. **FAO (2008) Ghanem and Basiouny (2010)** stated that there are many problems associated with agricultural waste. These problems are the difficulty of decomposition due to higher content of cellulose materials, waste spread over large areas which requires taking into account the assembly and transport process, low specific density of the waste, which leads to a problem in the storage, economic motives for the collection and transport not available, occupy large areas of the field during storage, containing rats and harmful insects, a good environment to ignite fires, and cause harmful environmental pollution when burned to humans, animals and field.

The total quantity of agricultural residues in Egypt is about 79 million ton. The quantity of palm, fruit and ornamental tree residues in year of 2014 are 4.3, 6.7 and 4.6 million ton respectively (Bulletin of Central Administration for Agricultural Extension Service, 2015)

From a point of view, the tree-branches chopping is necessary as a pretreatment to different uses. Mechanical treatment of the tree branches is done in order to convert it to small pieces, which are suitable for compost and energy briquetting. The tree-branches chopping process can be done by using variable types of chopping machines, but the productivity of these choppers is still little, not covering the manufactures needs in addition to the high operation and production cost of the chopping process.

Various types of size reduction equipment are available in the market. Based on the classification of size reduction equipment done by Schubert et al. (2004) and Woldt et al. (2004), Miu et al. (2006), an extended layout of this classification and suggested hammermill, knife mill, and disc mill are the proper equipment for biomass comminution.

Before turning branches into available energy, it needs special processing equipment to chop the branches into small pieces. This study introduces a new-invented system for tree-branch chopping which is biomass power generation preprocessing equipment. Most of the traditional chopping mechanism is a cutter disc structure and circular cutter structure. The cutter disc structure chopping mechanism has a big power and huge body that make the whole machine very heavy. So, the development of a new-invented system for tree-branches chopping can solve these two problems.

Abede Alrahman (2013) tested a developed knife for hammer mill chopper. It was found that by increasing concave-hole diameter from 5 to 10 mm, the power requirement decreased "from 5.26 to 5.13 kW", for rice straw and similar figures for corn stoves, etc...

Abo-Elasaad (2015) and Abo-Habaga et al. (2016) developed a rice straw bales chopper. It was found that the maximum value of power requirement and specific energy about 7.17 kW and 7.75 kW. h/t were obtained by using cutting-knives speed of 1260 rpm (26.4 m/s) and 750 rpm (15.71 m/s), platform tilt-angle of 30 degree with using 24 cutting knives, respectively. Whereas, the minimum value of power requirement and specific energy about 3.72 kW and 5.07 kW.h/t were obtained by using cutting-knives speed of 750 rpm (15.71 m/s) and 1260 rpm (26.4 m/s), platform tilt-angle of 20 degree with using 12 cutting knives respectively.

Okasha et al. (2015) found that the cutting productivity increased with increasing cutting-drum speed. For example the productivities were 107.1 and 150.2 kg/h with increasing cutting-drum speed from 1600 to 2200 rpm for 1.5 cm concave holes diameter.

The objectives of this research are:

- Developing, constructing and testing a new-invented system for tree-branches chopping.
- Studying the performance factors, such as "feeding-drums, cutting and chopping-knife speeds, tree-branches diameter and moisture content, concave-hole diameter and clearance" on cutting and chopping length, machine capacity, power requirements and cost of new-invented system for tree-branches chopping.

2. MATERIALS AND METHODS

2-1- Materials.

2-1-1 The new invented system for tree-branches chopping:

The developed new-invented system for tree-branches chopping photograph views are shown in fig. 1. The developed system consists of the following parts:

(1) Frame: The frame was made of L-section steel with dimensions of 70 x 70 x 7 mm. The overall length, width and height of frame are 1935, 680 and 740 mm respectively.

(2) Stands: Four stands are used to adjust the stability of the machine. The stands were made of iron square-tubes with thickness of 3 mm. Each stand consists of two telescopic tubes. The internal small tube has dimensions of 80 x 80 x 600 mm and the external tube has dimensions of 100 x 100 x 600 mm.

(3) Tires: Two rubber tires with diameter of 680 mm and width of 200 mm were assembled with the machine frame by square shaft welded with the frame by two plates.

(4) Draw-bar: Draw-bar made of sheet iron with length of 700 mm, width of 60 mm and thickness of 50 mm. The edge of draw-bar was welded with center of the frame. The other edge of bar has a hole with diameter of 30 mm to be trailed by a tractor.

(5) Feeding unit:

The feeding-unit assembly is shown in fig. 2. It consists of the following parts:

(5-a) Feeding housing: The feeding housing was made of sheet steel with 20 mm thickness. The top side length and width are 500 and 400 mm respectively. The bottom side length and width are 500 and 500 mm respectively. And the right and left sides width and height are 500 and 450 mm respectively. The overall length, width and height of feeding housing are ٥٠٠, 54٠ and ٥٨٥ mm respectively.

(5-b) Feeding drums: The two fluted feeding-drums were made of steel tube with 170 mm diameter, ٦ mm thickness and 400 mm length. The flute width, height and pitch are 3.5, 3.5 and 5 mm respectively. The gap between the two feeding-drums was 15 mm. The feeding-drum shafts diameter and length were 70 – 50 and 56 mm respectively. The two drums were assembled inside feeding housing.

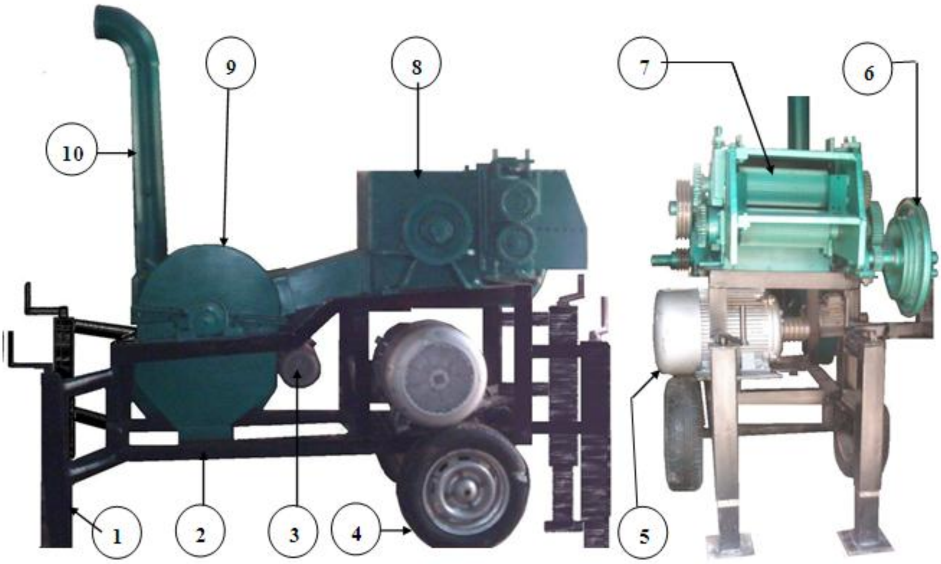


Fig. 1: Photograph views of the new invented-system for tree-branches chopping.

(1) Stand, (2) Frame, (3) Fan 1-hp motor, (4) Tire, (5) 20-hp motor, (6) Power transmission, (7) Feeding mechanism, (8) Cutting mechanism, (9) Chopping mechanism and (10) Duct.

(5-c) Pressing springs: Four pressing springs with 50 mm diameter, 10 mm thickness and 100 mm length were hinged in the top of two sides of the feeding drums, as shown in fig. 2. Each two springs were hinged on the top of sides of upper feeding-drum bearing. The tree branch diameters higher than the gap between feeding drums push the upper drum by pressing springs.

(6) Cutting unit:

The cutting-unit assembly is shown in fig. 3. It consists of the following parts:

(6-a) Cutting-unit housing: The cutting-unit housing was made of sheet steel with 20 mm thickness. The top and bottom-sides length and width are 500 and 500 mm respectively. And the right and left sides have length and width 500 and 500 mm respectively. The overall length, width and height of the housing cutting unit are 500, 540 and 500 mm respectively.

(6-b) Rotating cutting-knives: The three rotating cutting-knives were made of alloy steel “K100” with 20 mm thickness, 80 mm width and 400 mm length. The knives were assembled with plates welded on star discs. Each knife has five holes with 6 mm diameter. The steel type of the cutting knife is branded "Bohler K100 or DIN 1.2080

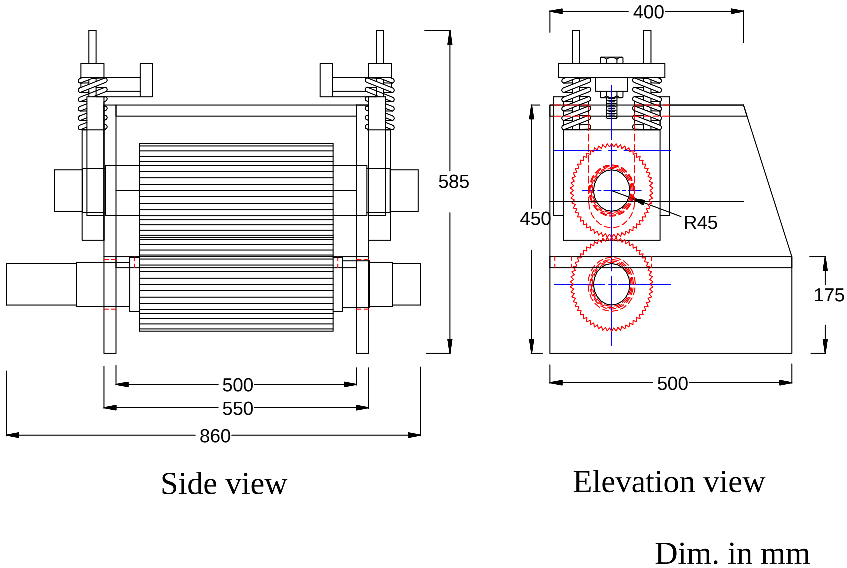


Fig. 2: Assembly views of the feeding unit.

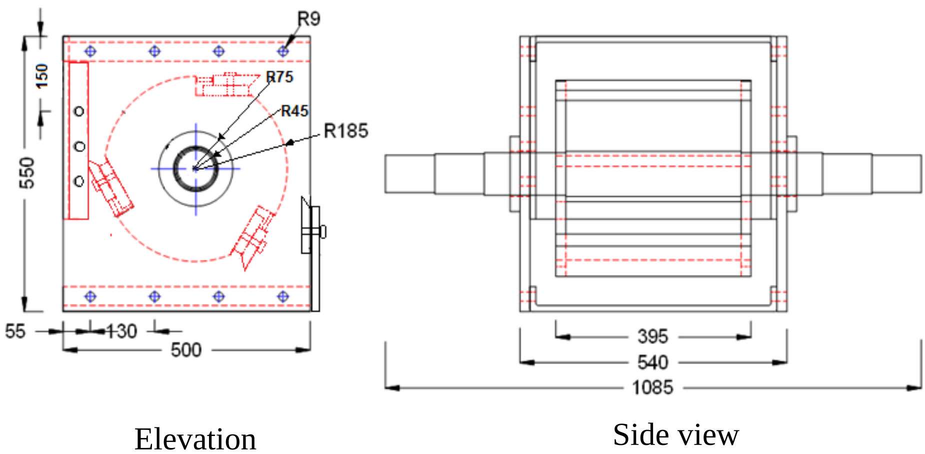


Fig. 3: Assembly drawing of the cutting unit.

Table 1: The chemical composition of cutting knives alloy-steel "K100" (Bohler Co. – 2006).

The elements, %.					
C	Si	Mn	Cr	Ni	W
1.98	0.19	0.32	11.84	0.18	0.05

The hardness of the knife steel was in the range of 63 – 65 HRC (Hardness Rockwell Scale).

X210Cr12". The chemical compositions of cutting knives alloy-steel "K100" is shown in table 1.

(6-c) Star discs and plates: Three star-discs made of sheet steel with 370 mm diameter, 20 mm thickness. Each disc has three grooves. The disc-groove length, width and height are 120, 80 and 20 mm respectively. Three plates are welded with grooves of three discs. Each plate has 5 sluts with dimensions of 60 x 20 mm.

(6-d) Fixed knife: The three fixed knife was made of alloy steel "K100" with

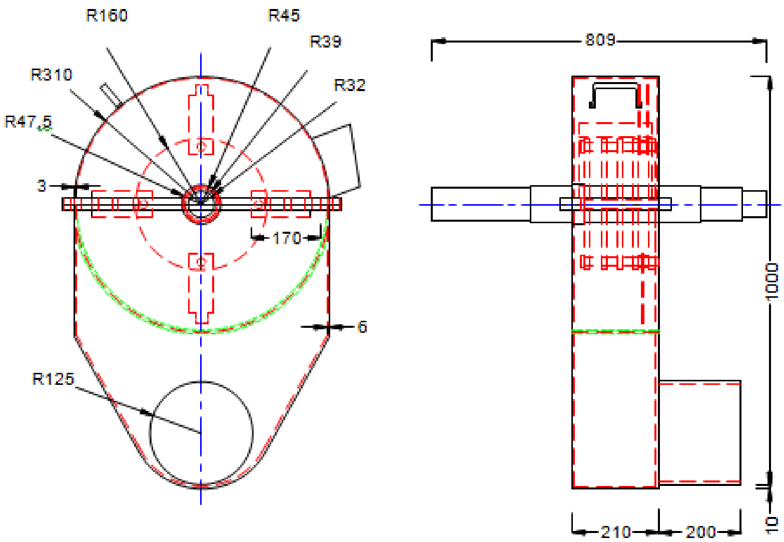
20 mm thickness, 80 mm width and 400 mm length. **(7) Conveying tunnel:** The conveying tunnel connects the outlet of cutting unit and inlet of chopping unit. The tunnel was made of sheet metal with thickness of 2 mm. The dimensions of the tunnel side connected with chopping-outlet of cutting unit are 500 x 200 mm. And the dimensions of tunnel side connected with inlet of chopping unit are 200 x 200 mm.

(8) Chopping unit:

The chopping-unit assembly drawing is shown in fig. 4. The chopping unit consists of the following parts:

(8-a) Chopping housing: The circular feeding-housing was made of sheet steel with 6 mm thickness. The housing divides into two parts. The 60 plates with dimensions of 200 x 15 x 15 mm were welded inside the top of upper half of feeding housing. The top and bottom side length and width are 620 and 200 mm respectively. The overall length, width and height of chopping housing are 1000, 680 and 270 mm respectively.

(8-b) Chopping-unit shaft and flanges: Chopping-unit shaft was made of steel with maximum diameter of 98 mm and length of 809 mm. The chopping-unit shaft is mounted with machine frame by two ball-bearings. Five steel flanges with diameter of 320 mm and thickness of 8 mm were welded with chopping unit shaft. Each flange has 4 holes with diameter of 20 mm. The flanges spacing was 20 mm.



Elevation view Side view

Dim. in mm.

Fig. 4: Assembly views of the cutting unit.

(8-c) Chopping knives, sleeve rings and pins: Twenty four free chopping-knives were made of steel sheet. Each chopping knife has thickness of 6 mm, length of 170 cm and width of 60 mm. The chopping knives statically and dynamically were balanced with respect to the chopping-shaft assembly at private workshop. The chopping-knives were hinged between flanges by 24 sleeve rings and 4 pins. The twenty four free-knives were arranged with 4 rows. The first pairs faced-rows have 16 knives (each row has 8 knives) and the other pairs faced-rows have 8 knives (each row has 4 knives). The knife existing in the row which has 16 knives was hinged between two flanges by one sleeve rings inserted between two knives. Meanwhile, the knife exist in the row which have 8 knives was hinged between two flanges by two sleeve rings in two knife sides. Eight sleeve rings had length of 7 mm, inlet diameter of 21 mm and outer diameter of 30 mm. Meanwhile, sixteen sleeve-rings had length of 6 mm and the same diameters. Each pin has diameter of 20 mm and total length of 190 mm. The pin head height and diameter are 10 and 26 mm respectively. Each pin fixed with the flange in the other side of pin head by a vertical Allen socket head grub-type screw with diameter of 5 mm and length of 10 mm.

(9) Connected tubes: The connecting tubes connect the outlet of chopping unit and inlet of blower fan. The connecting tubes were made of sheet metal with diameter of 200 mm and thickness of 3 mm. The first connecting tube welded with chopping unit has length of 200 mm. The second tube was welded with blower-fan housing with length of 200 mm. The two connecting tubes were connected face to face and warped with rubber coil. The rubber coil was held with two connecting tubes by clamp.

(10) Suction and expulsion unit: The suction and expulsion unit consists of blower-fan assembly and expulsion duct. The blower fan assembly consists of the following parts:

(10-a) Housing: made of sheet iron with thickness 3 mm. The maximum length, width and height of the blower-fan housing are 620, 378 and 945 mm respectively. Figs. 1 and 2 show views and photograph of the blower-fan housing.

(10-b) Blower fan: made of sheet iron with thickness of mm. The diameter and width of the fan are 350 and 100 mm respectively. The blower fan has 14 vanes. The vanes were made of sheet iron with 3 mm thickness.

(10-c) Blower-fan shaft: made of steel with diameter of 24 mm and maximum length of 300 mm.

(10-d) The expulsion duct: is made of steel tube with diameter of 150 mm, length of 1020 mm and thickness of 3 mm.

(11) Electrical motors: The investigated chopper was designed to use two power movers as follows:

(11-a) First motor: three phase induction electrical-motor of 15.4 kW (20 hp) and 970 rpm was assembled with the frame to drive feeding, cutting and chopping units only in experimental tests by means of pulleys, v-belts and gear drives. After the optimum speeds, all machine units can be operated by the 15.4 kW motor. The electrical motor is equipped with a movable base using four bolts to be able to replace and change the tested pulleys.

(11-b) Second motor: single phase induction motor of 0.75 kW (1 hp) and 1400 rpm was assembled with the blower-fan assembly base to drive the suction blower-fan only in experimental tests. Primary experiment-tests for blower-fan speeds were conducted to determine the optimum speed which was 1400 rpm. This motor is equipped with fixed base using four bolts.

(12) Power transmission-unit: The power was transmitted from the electrical motor by means of pulleys and v-belts drives. The motor-shaft pulley with diameter "D_1" of 120 mm is on the chopping-knives shaft pulleys with diameter "D_2" of 97, 106, 116 and 130 mm. The chopping-knives shaft carries a pulley with tested diameters "D_3" of 140 mm at the other direction of chopping-unit shaft. The last pulley "D_3" is connected with pulley with tested diameters "D_4" of 228. 253, 285 and 325 mm which was carried on cutting-unit shaft. The cutting-knives shaft carries a pulley of diameter "D_4" of 100 mm at the other direction of cutting-unit shaft. The last pulley "D_5" is connected with pulley with tested diameters "D_6" of 220. 263, 360 and 600 mm which was carried on an a handle shaft. The small gear "Gear 1" with diameter 10 cm and number of teeth of 10 is bolted to the same handle shaft. The small gear "Gear 1" is connected with the lower drum feeding-shaft gear "Gear 2" with diameter of 60 cm and number of teeth 57. The lower drum feeding shaft carries two gears with 36 teeth at two direction of it. The last two gears connected with two gears "Gear 3 and Gear 4" with 36 teeth to transmit the motion to the upper feeding-drum. The above mentioned power transmission arrangement of feeding-drum, cutting-knife and chopping-knife speeds are shown in table 2.

The constant tested blower-fan speed of 1400 rpm was obtained using another motor with 0.75 kW power and 1400 rpm speed.

2-1-2 Tree branches: "Ficus nitida" tree-branches with diameters of 20, 30, 40 and 50 mm and moisture content of 10 % wet base were used in the experimental tests.

Table 2: Tested motor, chopping shaft pulley diameters and chopping knife speeds at constant feeding-drum speed of 10 rpm and cutting-knives speed of 450 rpm.

Motor pulley diameter, mm. (D_1)	Chopping-shaft pulley diameter, mm. (D_2)	Chopping-knives speed, rpm.	Chopping-knives speed, m/s.
120	130	900	27.31
	116	1000	30.35
	106	1100	33.38
	97	1200	36.42

2-2 Methods:

(1) Studied factors.

The experiments were conducted to study some factors affecting the chopping-unit performance such as chopping-knives speed, concave-hole diameter, tree-branch diameter at tree-branches moisture content of 10 %, feeding-drum speed of 10 rpm (0.083 m/s), cutting-knife speed of 450 rpm (8.47 m/s) and clearance between chopping-knife tips and chopping-housing roof is 5 mm. The studied parameters were as follows:

(a) Chopping-knives speeds: The tested chopping-knife speeds were 900, 1000, 1100, and 1200 rpm (27.31, 30.35, 33.38 and 36.42 m/s).

(b) Concave-hole diameters: The tested concave-hole diameters were 14, 16, 18 and 20 mm.

(d) Tree-branche moisture contents: The tested tree-branch moisture contents were 10, 15, 20 and 25 % in wet base.

(e) Tree-branch diameters: The tested tree-branch diameters were 20, 30, 40 and 50 mm.

(2) Measurements:

(a) Average and percentage chopping-length of tree branches: Average chopping-length for tree branches produce from chopping unit was measured from sample of 200 g for each treatment. Six categories of "< 4", "4 – 8", "8 – 12", "12 – 16", "16 – 20" and "> 20" mm were measured. Also each chopping length in the sample was weighed and calculated as a percentage from the total weight of the sample.

(b) Machine productivity: Machine productivity was calculated by using the following equation**:**

$$P = W / t \text{ ………… (2-1)}$$

Where: **P** : Machine productivity, kg/h, **W**: Mass of the rice straw bale, kg and **t** : Time, h.

(d) Power requirement and specific energy: The electrical power requirement (kW) was calculated by using the clamp meter to measure the line current strength in Amperes (I) and potential difference values (v). The required power of developed new invented system for tree-branches chopping with and without load (P) was calculated according to **Kurt, 1979** by using the following equation:

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

Where: **P**: Power requirement for the cutting machine in kW, **I** : Line current intensity in amperes, **V**: Voltage being equal to 380 V, **Cos θ** : Power factor (taken to 0.85), $\sqrt{3}$: Coefficient current three phase and **η**: Mechanical efficiency assumed (95 %).

The specific energy was calculated by using the following equation:

$$\text{Specific energy, kW.h/ton} = \frac{\text{Power, kW}}{\text{Productivity, ton/h}} \quad \text{……… (2-3)}$$

(e) Estimating the costs of using the machine: Cost of operation was calculated according to the equation given by **Awady, 1978,** in the following form:

$$C = p/h\,(1/a + i + t/2 + r) + (Ec * Ep) + m/144 \quad \text{…… (2-4)}$$

Where: **C**: hourly cost, LE/h, **P**: price of machine, LE, **h**: yearly working hours, h, **a**: life expectancy of the machine, year, **i**: interest rate/year, **t**: taxes, (0.05), **r**: overheads and indirect cost ratio (0.03), **Ec**: Electricity consumption kW, **Ep**: Electricity price L.E/kW.h, **m**: Monthly wage and

"144" are estimated monthly working hours. Notice that all units have to be consistent to result in L.E/h.

Production cost was calculated according to the following equation:

$$\text{Production cost, L.E./ton} = \frac{\text{Operation cost, L. E./ h}}{\text{Machine productivity, ton/h}} \quad \dots (2\text{-}5)$$

RESULTS AND DISCUSSION

(1) Effect of tree-branch diameter, chopping-knives speed, concave hole-diameter on average of chopping-length at clearance of 5 mm, moisture-content of 10 %, cutting-knives speed of 450 rpm and feeding-drums speed of 10 rpm.

Fig. 5 shows the effect of tree-branches diameter, chopping-knives speed and concave-hole diameter on average of chopping length.

The maximum average of chopping length of 19 mm was obtained by using chopping-knives speed of 900 rpm (27.31 m/s), concave-hole diameter of 20 mm and tree-branch diameter of 50 mm. Meanwhile, the minimum average of chopping length of 6 mm was obtained by using chopping-knives speed of 1200 rpm (36.92 m/s), concave-hole diameter of 14 mm and tree-branch diameter of 20 mm (at constant clearance of 5 mm, moisture-content of 10 %, cutting-knives speed of 450 rpm and feeding-drums speed of 10 rpm).

(a) Effect of tree-branches diameter.

By increasing tree-branch diameter from 20 to 50 mm the average of chopping length increased by 22.5 at all tested concave-hole diameters and chopping-knife speeds.

The increasing of average chopping-length of tree branches by increasing tree-branches diameter is due to increasing the volume of the branches which need number of knife hits more than the smaller branch diameters.

(b) Effect of chopping-knives speed.

By increasing chopping-knives speed from 900 to 1200 rpm (from 27.31 to 36.92 m/s) the average of chopping length decreased by 12.83 at all tested concave-hole diameters and tree-branch diameters.

The decreasing of average chopping-length of tree branches by increasing chopping-knives speed is due to increasing number of hits of chopping knives to tree-branches.

(c) Effect of concave-hole diameter.

By increasing concave-hole diameter from 14 to 20 mm the average of chopping length increased by 35 % at all tested chopping-knife speeds and tree-branch diameters.

The increasing of average chopping-length of tree branches by increasing concave-hole diameter is due to decreasing number of hits of chopping knives to tree-branches because of escaping the branches through concave holes.

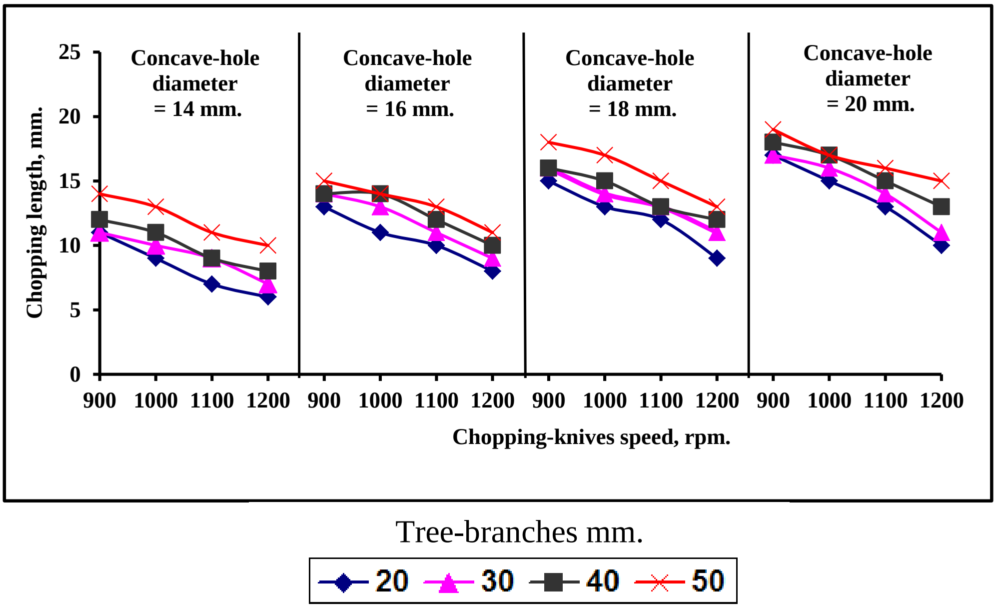


Fig. 5: Effect of tree-branches diameter, chopping-knives speed and concave-hole diameter on average of cutting length by using clearance of 5 mm and branches moisture-content of 10 %.

(2) Effect of tree-branch diameter, chopping-knives speed and concave hole-diameter on chopping-length percentage at clearance of 5 mm, moisture-content of 10 %, cutting-knives speed of 450 rpm and feeding-drums speed of 10 rpm.

Figs. 6 and A-1 in appendix show the effect of tree-branches diameter, concave-hole diameter and chopping-knives speed on chopping-length percentage at clearance of 5 mm, moisture-content of 10 %, chopping-knives speed of 450 rpm and feeding-drums speed of 10 rpm.

The maximum percentage of chopping-length of 82.4 % was obtained with size category of 4 – 8 mm at chopping-knives speed of 1200 rpm

(36.92 m/s), concave-hole diameter of 14 mm and tree-branches diameter of 20 mm. Meanwhile, the minimum percentage of chopping-length of 1.9 % was obtained with size category of 12 - 16 mm at chopping-knives speed of 1200 rpm (36.92 m/s), concave-hole diameter of 14 mm and tree-branches diameter of 20 mm.

Table 3 shows the maximum and minimum values of chopping-length percentage by contrast values of chopping-knives speed, concave-hole diameter and tree-branches diameter.

The maximum percentage of chopping-length size less than 4 mm (< 4 mm) of 13.1 % was obtained at chopping-knives speed of 1200 rpm (36.92 m/s), concave-hole diameter of 14 mm and tree-branches diameter of 20 mm. Meanwhile, the minimum percentage of chopping-length size less than 4 mm (< 4 mm) of zero % was obtained at chopping-knives speed of 900 -1200 rpm (27.31 -36.92 m/s), concave-hole diameter of 18 - 20 mm and tree-branches diameter of 30 – 50 mm.

The maximum percentage of chopping-length size of 82.4 % was obtained at chopping-knives speed of 1200 rpm (36.92 m/s), concave-hole diameter of 14 mm and tree-branches diameter of 20 mm.Meanwhile, the minimum percentage of chopping-length size 4 - 8 mm of zero % was obtained at chopping-knives speed of 900 -1200 rpm (27.31 -36.92 m/s), concave-hole diameter of 20 mm and tree-branches diameter of 50 mm.

The maximum percentage of chopping-length size 8 – 12 mm of 70.9 % was obtained at chopping-knives speed of 1200 rpm (36.92 m/s), concave-hole diameter of 18 mm and tree-branches diameter of 50 mm. Meanwhile, the minimum percentage of chopping-length size 8 - 12 mm of 2.6 % was obtained at chopping-knives speed of 1200 rpm (36.92 m/s), concave-hole diameter of 14 mm and tree-branches diameter of 20 mm.

The maximum percentage of chopping-length size 12 - 16 mm of 43.1 % was obtained at chopping-knives speed of 900 rpm (27.31 m/s), concave-hole diameter of 20 mm and tree-branches diameter of 40 mm. Meanwhile, the minimum percentage of chopping-length size 12 - 16 mm of 1.9 % was obtained at chopping-knives speed of 1200 rpm (39.92 m/s), concave-hole diameter of 14 mm and tree-branches diameter of 20 mm.

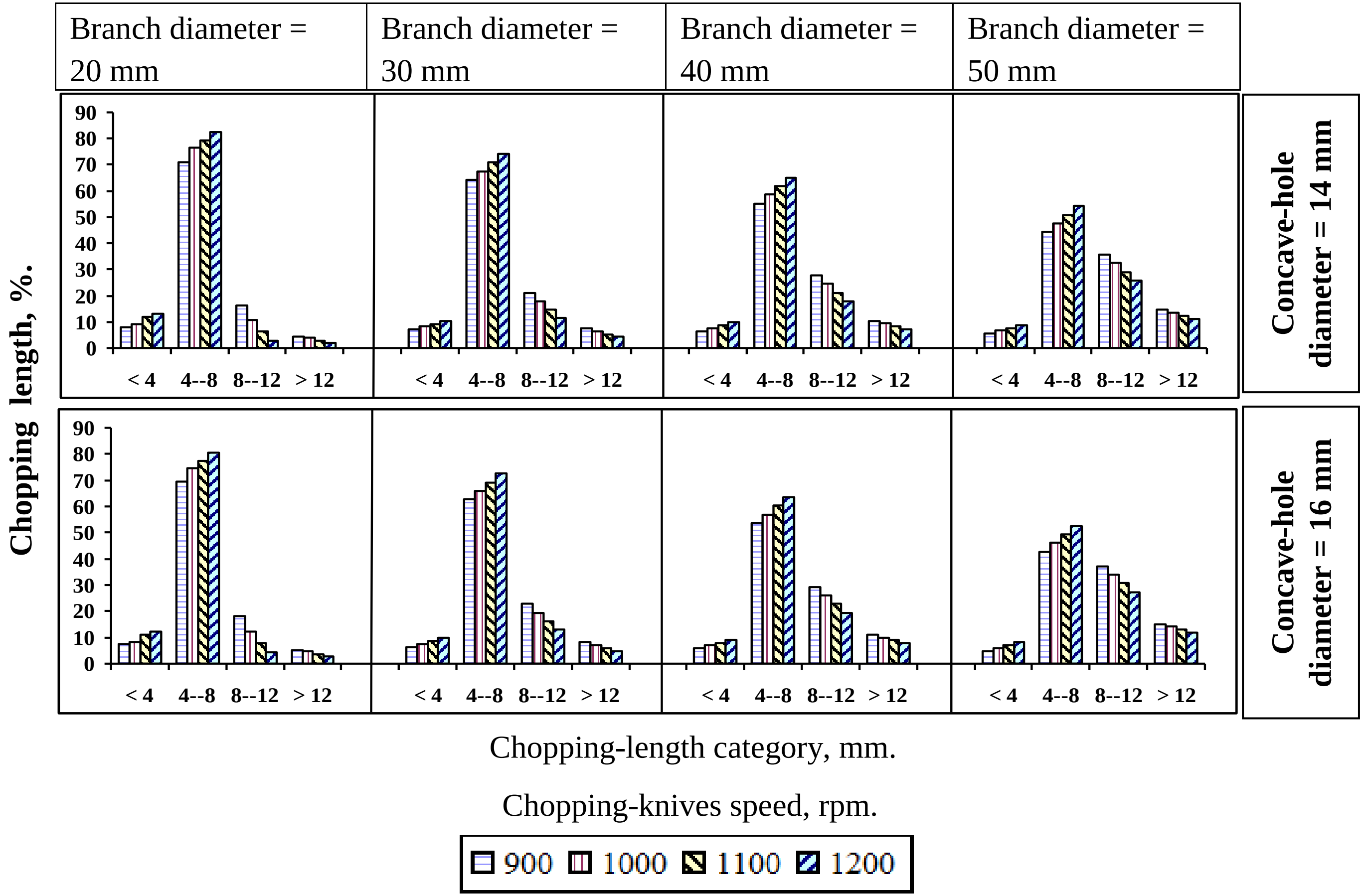


Fig. 6: Effect of chopping-knives speed and tree-branch diameter on chopping-length percentage at concave hole-diameter of 14 and 16 mm.

The maximum percentage of chopping-length size 16 – 20 mm of 57.1 % was obtained at chopping-knives speed of 900 rpm (27.31 m/s), concave-hole diameter of 20 mm and tree-branches diameter of 50 mm. Meanwhile, the minimum percentage of chopping-length size 16 – 20 mm of zero % was obtained at chopping-knives speed of 900 – 1200 rpm (27.31 – 39.92 m/s), concave-hole diameter of 16 mm and tree-branches diameter of 20 - 50 mm, and concave-hole diameter of 18 mm and tree-branches diameter of 20 mm.

Table 3: Maximum and minimum values of chopping-length percentage by contrast values of chopping-knives speed, clearance, concave-hole diameter and tree-branches diameter.

Chopping-length category, mm.	Maximum and minimum values.	Chopping length, %.	Chopping-knives speed, rpm.	Concave-hole diameter, mm.	Tree-branches diameter, mm.
< 4	Maximum values.	13.1	1200	14	20
4--8		82.4	1200	14	20
8--12		70.9	1200	18	30
12--16		43.1	900	20	40
16 - 20		57.1	900	20	50
> 20		30.3	900	20	50
< 4	Minimum values.	0	900 - 1200	18 - 20	30 - 50
4--8		0	900 - 1200	20	50
8--12		2.6	1200	14	20
12--16		1.9	1200	14	20
16 - 20		0	900 - 1200	16 18	20 – 50 20
> 20		0	900 - 1200	14 – 18 20	20 – 50 20 - 40

The maximum percentage of chopping-length size more than 20 mm (> 20 mm) of 30.3 % was obtained at chopping-knives speed of 900 rpm (27.31 m/s), concave-hole diameter of 20 mm and tree-branches diameter of 50 mm. Meanwhile, the minimum percentage of chopping-length size more than 20 mm (> 20 mm) of zero % was obtained at chopping-knives speed of 900 – 1200 rpm (27.31 – 39.92 m/s), concave-hole diameter of 14 - 18 mm and tree-branches diameter of 20 - 50 mm, and concave-hole diameter with tree-branches diameter of 20 – 40 mm.

(3) Effect of tree-branch diameter, chopping-knives speed, concave hole-diameter on machine productivity at clearance of 5 mm, moisture-content of 10 %, cutting-knives speed of 450 rpm and feeding-drums speed of 10 rpm.

Fig. 8 shows the effect of tree-branches diameter, chopping-knives speed and concave-hole diameter on machine productivity.

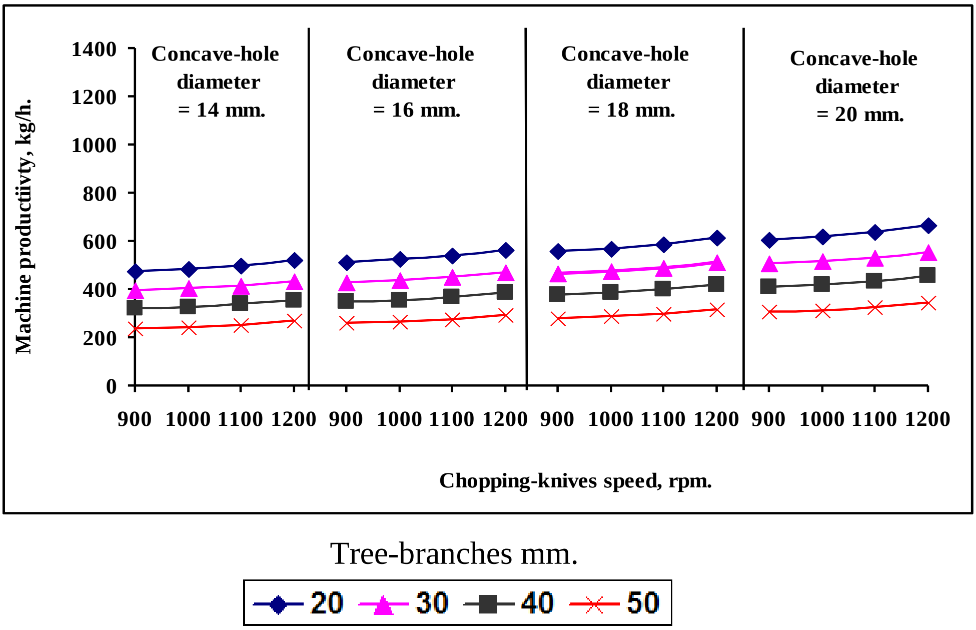


Fig. 8: Effect of tree-branches diameter, chopping-knives speed and concave-hole diameter on machine productivity by using clearance of 5 mm and branches moisture-content of 10 %.

The minimum productivity of 238 kg/h was obtained by using chopping-knives speed of 900 rpm (27.31 m/s), concave-hole diameter of 14 mm and tree-branch diameter of 50 mm. Meanwhile, the maximum machine productivity of 667 kg/h was obtained by using chopping-knives speed of 1200 rpm (36.92 m/s), concave-hole diameter of 20 mm and tree-branch diameter of 20 mm (at constant clearance of 5 mm, moisture-content of 10 %, cutting-knives speed of 450 rpm and feeding-drums speed of 10 rpm).

(4) Effect of tree-branch diameter, chopping-knives speed, concave hole-diameter on power requirement and specific energy at clearance of 5 mm, moisture-content of 10 %, cutting-knives speed of 450 rpm and feeding-drums speed of 10 rpm.

Fig. 9 shows the effect of tree-branches diameter, chopping-knives speed and concave-hole diameter on power requirement and specific energy.

The maximum power requirement of 14.6 kW was obtained by using chopping-knives speed of 1200 rpm (36.92 m/s), concave-hole diameter of 14 mm and tree-branch diameter of 50 mm. Meanwhile, the minimum power requirement of 11.3 kW was obtained by using chopping-knives speed of 900 rpm (27.31 m/s), concave-hole diameter of 20 mm and tree-branch diameter of 20 mm (at constant clearance of 5 mm, moisture-content of 10 %, cutting-knives speed of 450 rpm and feeding-drums speed of 10 rpm).

The maximum power specific energy of 56.8 kW.h/ton was obtained by using chopping-knives speed of 900 rpm (27.31 m/s), concave-hole diameter of 14 mm and tree-branch diameter of 50 mm. Meanwhile, the minimum specific energy of 18.4 kW.h/ton was obtained by using chopping-knives speed of 1200 rpm (36.92 m/s), concave-hole diameter of 20 mm and tree-branch diameter of 20 mm (at constant clearance of 5 mm, moisture-content of 10 %, cutting-knives speed of 450 rpm and feeding-drums speed of 10 rpm).

(5) Effect of tree-branch diameter concave hole-diameter on operation and production costs at tree-branches moisture content of 10 %, feeding-drums speed of 10 rpm (0.083 m/s), cutting-knives speed of 450 rpm (8.47 m/s), chopping-knives speed of 1100 rpm (33.38 m/s) and clearance of 5 mm.

Table 4 shows the components of the Awady equation and operation and production costs of using the designed granular processing-machine.

Table 4: The components of Awady equation.

p, L.E.	h, h	a, year	i	t	r	Ec, kW.h/h	Ep, L.E.	m, L.E
40000	30000	10	0.075	0.05	0.03	11.7 – 15	0.30	1500

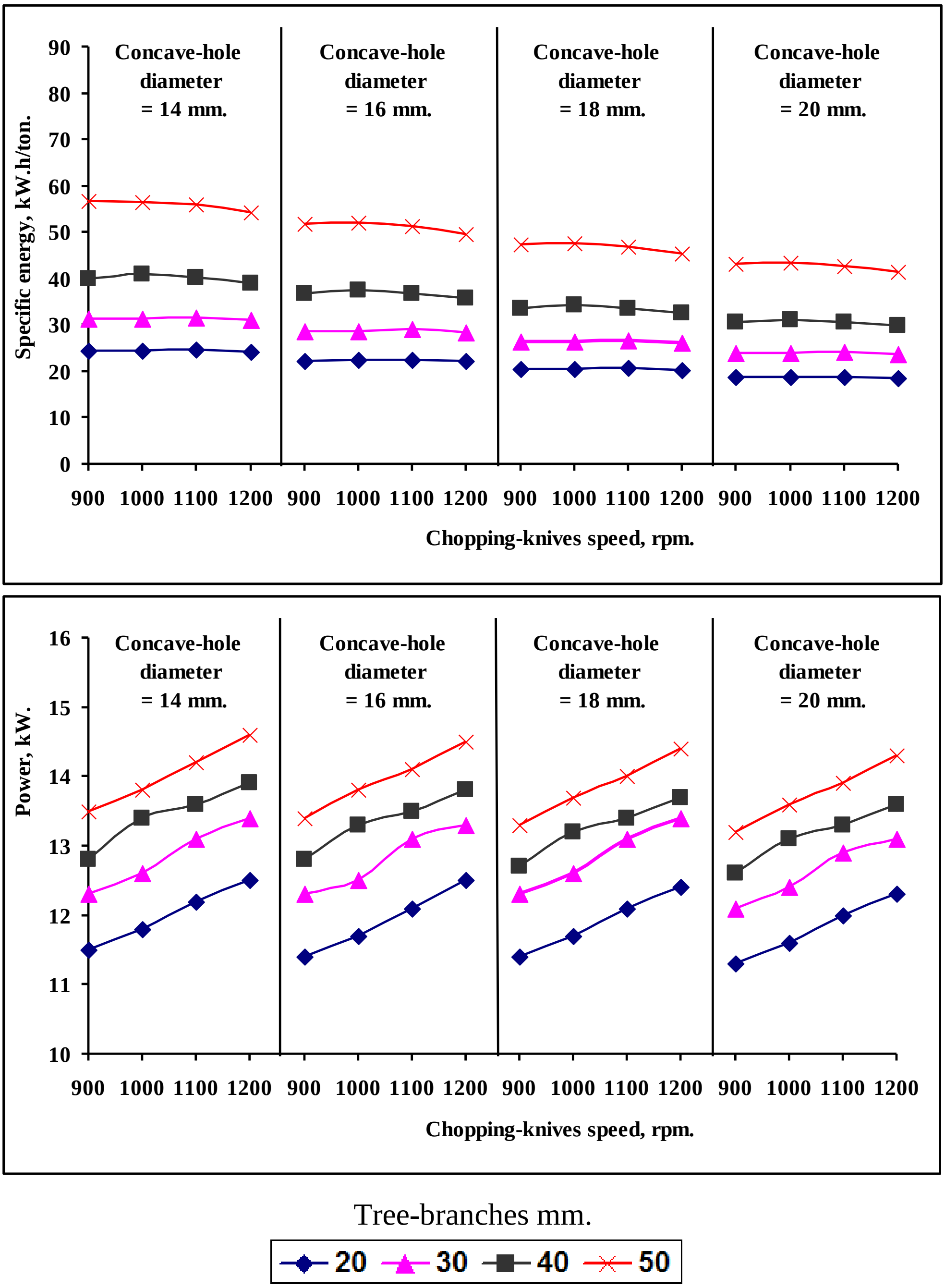


Fig. 9: Effect of tree-branches diameter, chopping-knives speed and concave-hole diameter on power requirement and specific energy using clearance of 5 mm and branches moisture-content of 10 %.

Table 5 shows the effect of concave-hole diameter and tree-branches diameter on operation and production costs at moisture content of 10 %, feeding-drums speed of 10 rpm (0.083 m/s), cutting-knives speed of 450 rpm (8.47 m/s), chopping-knives speed of 1100 rpm (33.38 m/s) and clearance of 5 mm.

Table 5: Effect of concave-hole diameter and tree-branches diameter on operation and production costs at moisture content of 10 %, feeding-drums speed of 10 rpm (0.083 m/s), cutting-knives speed of 450 rpm (8.47 m/s), chopping-knives speed of 1200 rpm (36.42 m/s) and clearance of 5 mm.

Concave-hole diameter, mm.	Tree-branches diameter, mm.	Power, kW.	Operation cost, L.E./h.	Machine productivity, kg/h.	Production cost, L.E./h.
14	20	12.4	17.42	519	33.56
	30	13.3	18.14	433	41.89
	40	13.8	18.41	356	51.70
	50	14.4	18.56	269	68.98
16	20	12.34	18.74	564	33.22
	30	13.25	18.12	470	38.55
	40	13.67	18.39	387	47.52
	50	14.3	18.52	293	63.20
18	20	12.26	18.71	613	30.52
	30	13.33	18.09	511	35.41
	40	13.59	18.42	420	43.85
	50	14.21	18.49	318	58.16
20	20	12.19	18.68	667	28.01
	30	13.1	18.07	556	32.51
	40	13.5	18.35	457	40.15
	50	14.15	18.47	346	53.37

The maximum operation cost of 18.71 L.E./h was obtained by using concave-hole diameter of 18 mm and tree-branch diameter of 20 mm. Meanwhile, the minimum operation cost of of 17.42 L.E./h was obtained by using concave-hole diameter of 14 mm and tree-branch diameter of 20 mm at moisture content of 10 % feeding-drums speed of 10 rpm (0.083 m/s), cutting-knives speed of 450 rpm (8.47 m/s), chopping-knives speed of 1100 rpm (33.38 m/s) and clearance of 5 mm.

The maximum production cost of 68.98 L.E./ton was obtained by using concave-hole diameter of 14 mm and tree-branch diameter of 50 mm. Meanwhile, the minimum production cost of of 28.01 L.E./ton was obtained by using concave-hole diameter of 20 mm and tree-branch diameter of 20 mm at moisture content of 10 % feeding-drums speed of 10 rpm (0.083 m/s), cutting-knives speed of 450 rpm (8.47 m/s), chopping-knives speed of 1100 rpm (33.38 m/s) and clearance of 5 mm.

CONCLUSION

The optimum conditions of a developed new-invented system for tree-branches chopping were: moisture content of 10 % feeding-drums speed of 10 rpm (0.083 m/s), cutting-knives speed of 450 rpm (8.47 m/s), chopping-knives speed of 1200 rpm (33.38 m/s), clearance of 5 mm, tree-branch diameter range of 20 – 50 mm and concave-hole diameter range of 14 - 20 mm. The results obtained at optimum conditions were: average chopping-length = 7 – 16 mm, machine-productivity = 269 - 667 kg/h, power-requirement = 11.7 – 14.1 kW, specific-energy = 18.4 – 54.2 kW.h/ton and costs of 17.42 – 18.71 L. E./h and 28.01 – 68.98 L.E./ton.

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Appendix

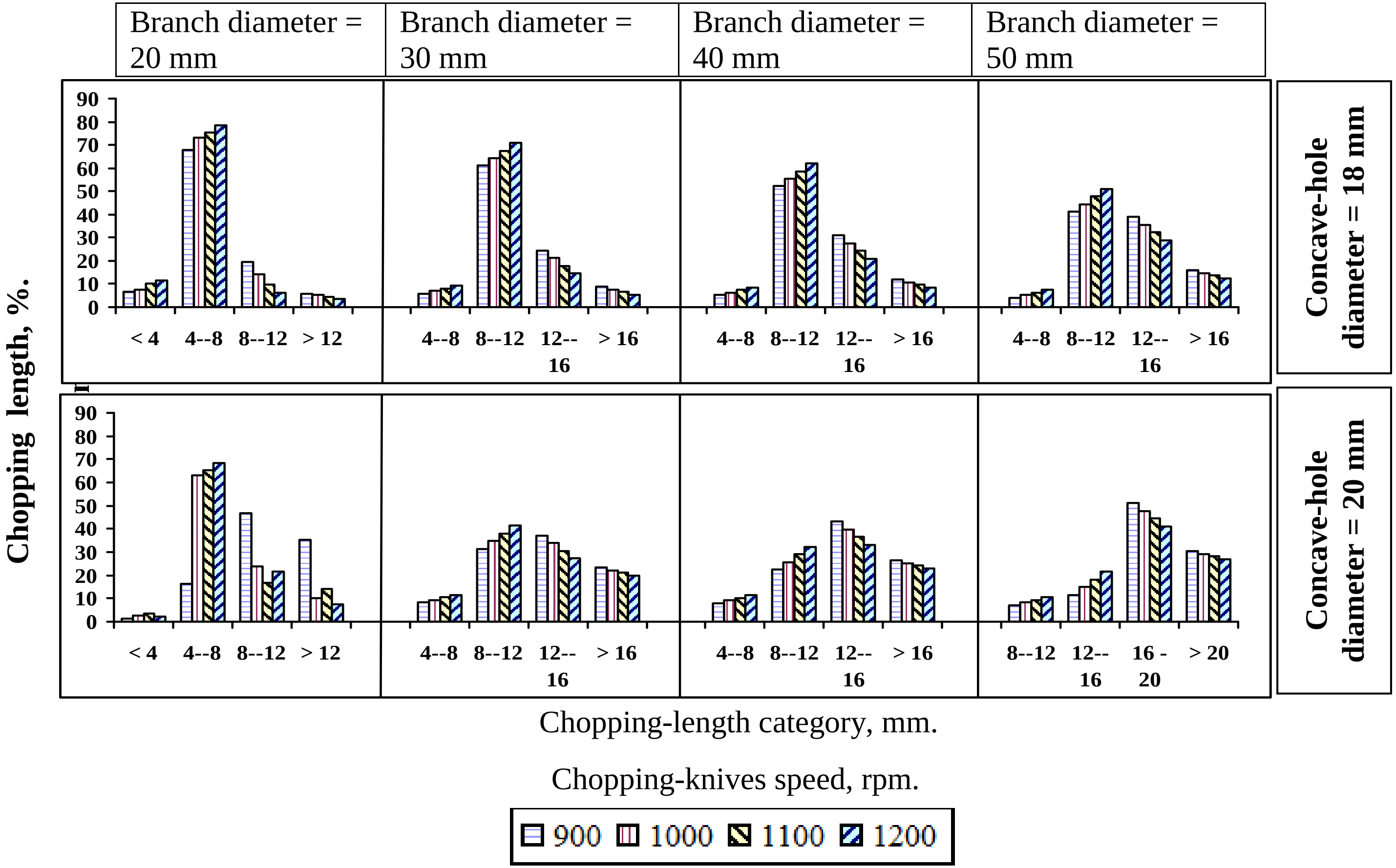

Fig. A-1: Effect of chopping-knives speed and tree-branch diameter on chopping-length percentage at concave hole-diameter of 18 and 20 mm.

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الملخص العربى

تطوير نظام جديد مبتكر لفرم أفرع الأشجار

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يهدف هذا البحث إلى تصميم نظام جديد مبتكر لفرم أفرع الأشجار، مع دراسة العوامل المؤثرة على تصميمها وأدائها. وتتكون الآلة من إطار، وحدة تغذية عبارةعن درفيلين، وحدة تقطيع، وحدة فرم، وحدة شفط وطرد المفروم، ومحرك قدرته ٢٠ حصان. ويقوم النظام المبتكر بتقطيع الأفرع إلى عقل عن طريق وحدة التقطيع، ثم يتم فرم العقل فى وحدة الفرم، ثم يتم سحب المفروم وطرده خارج الآلة بواسطة وحدة الشفط والطرد. وكانت عوامل الدراسة كالتالى: أربع سرعات لسكاكين الفرم: من ٩٠٠، إلى ١٢٠٠ لفة/د (من ٢٧.٣١ إلى ٣٦.٤٢ م/ث)، أربع أقطار ثقوب صدر: من ١٤إلى ٢٠ مم، أربعة أقطار أفرع أشجار الفيكس: من ٢٠ إلى ٥٠ مم مع رطوبة أفرع ١٠ % على أساس رطب، وخلوص ٥ مم، وسرعة درفيلى التغذية ١٠ لفة/د (٠.٠٨٣ م/ث) وسرعة سكاكين وحدة التقطيع ٤٥٠ لفة/د (٨.٤٧ م/ث). وكانت أهم النتائج المتحصل عليها كالتالى:

(١) **متوسط طول المفروم:** وجد أن أعلى متوسط لطول المفروم هو ١٩ مم وتم الحصول عليه عند سرعة سكاكين فرم ٩٠٠ لفة/د (٢٧.٣١ م/ث)، قطر ثقوب صدر ٢٠ مم، قطر أفرع ٥٠ مم. بينما وجد أن أقل متوسط لطول المفروم هو ٦ مم وتم الحصول عليه عند سرعة سكاكين فرم ١٢٠٠ لفة/د (٣٦.٤٢ م/ث)، قطر ثقوب صدر ١٤ مم، قطر أفرع ٢٠ مم.

(٢) **إنتاجية الآلة:** وجد أن أعلى إنتاجية للآلة هى ١٣٩٥ كج/س وتم الحصول عليها عند سرعة سكاكين فرم ١٢٠٠ لفة/د (٣٦.٤٢ م/ث)، قطر ثقوب صدر ٢٠ مم، قطر أفرع ٢٠ مم. بينما وجد أن أقل إنتاجية للآلة هى ١٨٤ كج/س وتم الحصول عليها عند سرعة سكاكين فرم ٩٠٠ لفة/د (٢٧.٣١ م/ث)، قطر ثقوب صدر ١٤ مم، قطر أفرع ٥٠ مم.

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(1) مهندس بوزارة التموين والتجارة الداخلية ـ القاهرة.

(٢) استاذ ورئيس قسم الهندسة الزراعية، بكلية زراعة مشتهر- جامعة بنها .

(٣) أستاذ ورئيس قسم نظم ميكنة العمليات الزراعية بمعهد بحوث الهندسة الزراعية.

(٤) و (٥) استاذ، قسم الهندسة الزراعية بكلية زراعة مشتهر- جامعة بنها.

(٣) متطلبات القدرة: وجد أن أعلى قدرة هى ١٤.٦ كيلووات وتم الحصول عليها عند سرعة سكاكين فرم ١٢٠٠ لفة/د (٣٦.٤٢ م/ث)، قطر ثقوب صدر ١٤ مم، قطر أفرع ٥٠ مم. بينما وجد أن أقل قدرة هى ١١.٣ كيلووات وتم الحصول عليها عند سرعة سكاكين فرم ٩٠٠ لفة/د (٢٧.٣١ م/ث)، قطر ثقوب صدر ٢٠ مم، قطر أفرع ٢٠ مم.

(٤) الطاقة النوعية: وجد أن أعلى طاقة نوعية هى ٥٦.٨ كيلووات.س/طن وتم الحصول عليها عند سرعة سكاكين فرم ٩٠٠ لفة/د (٢٧.٣١ م/ث)، قطر ثقوب صدر ١٤ مم، قطر أفرع ٥٠ مم. بينما وجد أن أقل طاقة نوعية هى ١٨.٤ كيلووات.س/طن وتم الحصول عليها عند سرعة سكاكين فرم ١٢٠٠ لفة/د (٣٦.٤٢ م/ث)، قطر ثقوب صدر ٢٠ مم، قطر أفرع ٢٠ مم.

(٥) تكاليف تشغيل الآلة: تراوحت التكاليف المتحصل عليها عند أنسب سرعة سكاكين فرم ١٢٠٠ لفة/دقيقة بين ١٧.٤٢ – ١٨.٧١ جنيه/ساعة، ٢٨.٠١ – ٦٨.٩٨ جنيه/طن.