EFFECT OF CUTTING PROCESS PARAMETERS ON CHIP PRODUCTION IN THAI PALM FARM USING AN ORBITAL CUTTING BLADE MACHINE

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ABSTRACT

This article presents an effect of cutting process parameters on chip production. The study involves cutting blade shape, a number of blades used, and feed angel for cutting a palm leaf-branch by an orbital cutting blade in chipping machine. Experiments were separated into two parts. The first part was a study on producing of an orbital cutting blade with heat treatment process. The results showed that carbon steel cutting blade should not apply the tempering after the hardening because it affected to decrease hardness and wear resistance of cutting edge. The second set of experiments was on applying the blade in chipping machine to study on parameter settings. The results can be summarized as follows. The half V cutting blade showed the higher wear resistance and hardness than that of the double V cutting blade for hardness of 481 HV and weight loss of 6.24%. The half V cutting blade produced higher and larger amount of palm chopping scrap and could produce the scrap of 3878 g at the cutting speed of 1200 rpm. Increasing in number of blades relatively affected to increase cutting efficiency including the increase in scrap amount and the smaller of scrap size. Feed direction that inclined to the horizontal axis but not over 45° could decrease a friction force and cutting force between the cutting edge and palm surface and also assisted in easy feeding.

KEYWORDS: cutting Blade, wear resistance, hardness, palm scrap

1. Introduction

Palm is a plant used in procuring palm oil. Most of palm oil in the marker is produced and exported from South-east Asia including Malaysia, Indonesia and Thai. A cultivated area in these countries in total is approximately 80 million km^2 [1]. For Thailand, palm is one of important economic plants. The Thai government has set a plan to increase its cultivated area to apply the palms for palm oil, soap and bio-diesel. The used part of the palm is mainly 20-30% of the fruit. Beside, palm leaf-branches are usable for feeding to ruminant animals [2]. The palm leaf-branches have several usages, and they need to be chipped for storage and transportation. Generally, chipping of palm leaf-branch has been done with expensive imported chippers.

For the reason, local farmers have been urged to have chippers small enough to put on a field tractor for mobility to use in a palm field, but suffice ability to chip with power from a tractor. With such conditions, studies have been made on shapes of a blade, development process and parameters of the cutting blade. There are several researches into this subject. The researches were made to study on using finite element method to analyze an effect of blade clearance. This provided a conclusion applicable on a design of blades for cutting a palm leaf-branch. The work found several interesting facts, but the noticeable ones are that shear strength was related to number of blades and space among them. Moreover, it provided evidence on effect of cutting angle and number of blades that may relatively result in different roughness of cut surface and strength of cutting [3].

Although, above research work applied various cutting process parameters for producing an optimum size and amount of various agricultural materials, but for a palm branch, the investigation was still limitation. Therefore, this research work was aimed to investigate effect of blade geometries, blade amount, and feed direction on palm cutting chip size and amount. The results obtained from the experiment might be useful for a design and a development of a chipping machine specifically for palm farming and alternative information for setting to farm mechanics.

2. Experimental Procedure

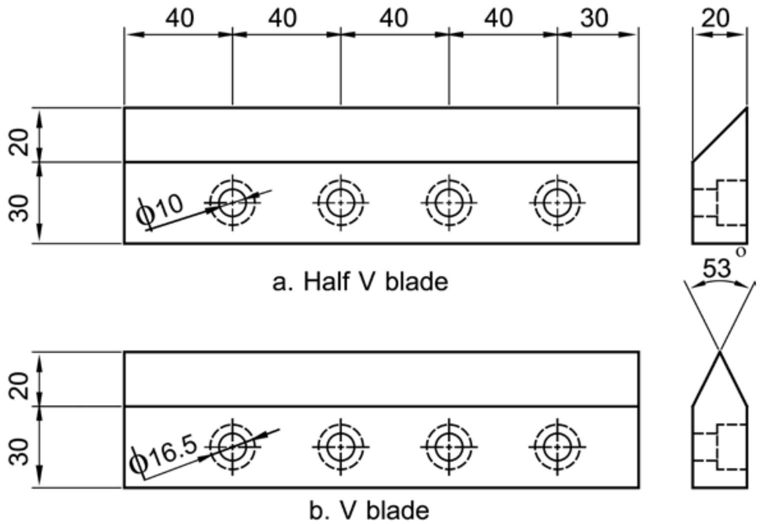

Figure 1 Blade geometric (Unit: mm)

Table 1 Chemical composition of the experimental material (wt%).

S45C carbon steel	Element
Fe	Balance
C	0.42
Si	0.43
Mn	0.67
P	0.02
S	0.02
Ni	0.04
Cr	0.98
Mo	0.17
Cu	0.01
Al	0.02
W	0.04

Materials for cutting blade in this experiment were a JIS-S45C carbon steel, and it has chemical compounds that analyzed by an optical emission spectrometry as listed in Table 1. The carbon steel was shaped using a CNC milling machine with a cooling medium. The cutting blade size was 50x190x18 mm for width, length and thickness, respectively as shown in Figure 1. The shape is in two forms, i.e. half V cutting blade and V cutting blade. The samples were processed with either hardening or tempering after hardening.

The samples were tested with wear rate for two parts. The first part is a cone of a blade. The cone was 25x50x20 mm for width, length and thickness. The second part is the blade end for 25x50 mm of width and length, and size of thickness depends on cutting edge. The wear resistance test was conducted by pressing the sample for 130 newtons on a rubber wheel surface for 200 rpm. While the sample and the rubber wheel were abrasive, 80 meshes of natural dried sand were added in between them for 30 minutes [4].

For hardness test, Micro Vickers machine was used to find a difference before and after heat treatment process. The test force was set to 300 grams for 10 seconds. The test aimed for two blade parts at the cone and end of the produced cutting blades. 15 areas were randomly tested with 0.5 mm area interval. Specifically, for end of cutting blade, hardness test was performed on at least 0.5 mm away from the edge and 0.1 mm away from blade surface.

The orbital cutting blade samples were also tested on chipping a palm leaf-branch. A cutting blade in chipper was for vertical cutting. The cutting speed for testing was performed in a range of cutting speed of 250-1200 rpm. In details, the palm leaf-branch in this test were gathered and measured as follows. The 100 specimens of palm leaf-branch were collected from a farm in amphor Thunyaburi, Pathumthani, Thailand during July to September 2016. The trees for collecting a specimen were approximately 3 years-old as average age with average height around 3 meters. The retrieved leaf-branches as specimens were cut from the trees. The specimens had an average weight per unit as 3.55 kg and length for 3,761 mm. The collected leaf-branch was consisted of leaf and branch. A length of leaf part was 971 mm in average. For the branch part, a base of a branch (thickest part of specimen) had average thickness for 34.74 mm and average width including sub-branches for 111.91 mm. An average thickness of middle and a tip of the branches were 27.19 and 2.16 mm while an average width were 31.14 mm and 2.16 mm, respectively. The details of palm leaf-branch specimens were sketched in Figure 2.

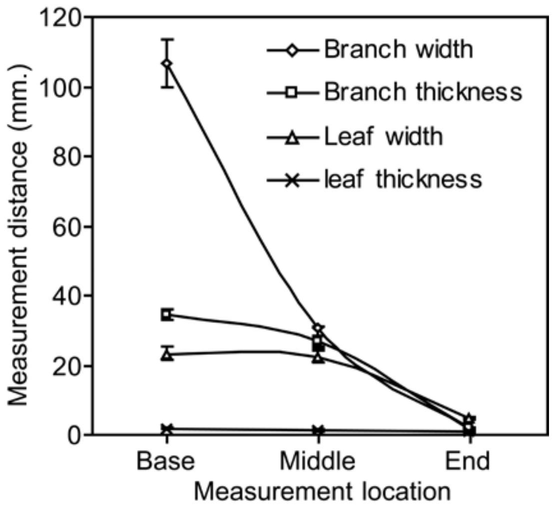

Figure 2 Palm geometries in a case study area

3 Experimental Results and Discussion

Figure 3 shows results of wear test. The weight loss in percentage represents a difference between weights before and after testing. The lower percentage of weight loss indicates the higher wear resistance and vice versa. The focused parts were cone and end of the blade from half V blade and V blade. Another factor is a variety of heat treatment processes including unprocessed, hardening and tempering after hardening. The results signified that the samples without heat treatment process obtained the highest weight loss for 7.45%. The best results were given for the samples with hardening process only while hardening and tempering produced higher percentage of weight loss in overall comparison. When comparing in blade part, the results show that the half V cutting blades were better in terms of wear resistance than the V blade.

For results of the hardness test given in Figure 4, the loss in weight affected the change in hardness. The samples processed with hardening apparently had higher hardness than the samples processed with hardening and tempering. The lower in hardness relatively resulted in the lower in wear resistance. In consideration of blade part, the end of the cutting blade was harder, and the half V blade samples obtained more hardness than the V shape sample. From analysis, difference in hardness was from the different thickness of blade part. The thicker carbon steel part had the lower rate in heat releasing [5] and shorter cooling rate. This wholly had effect on increasing in changing of microstructure of austenite phrase to martensite of a carbon steel within heat treatment process. Moreover, the increasing in martensite was from the increasing in temperature of tempering process in which can cause more grain size and boron segregation [6].

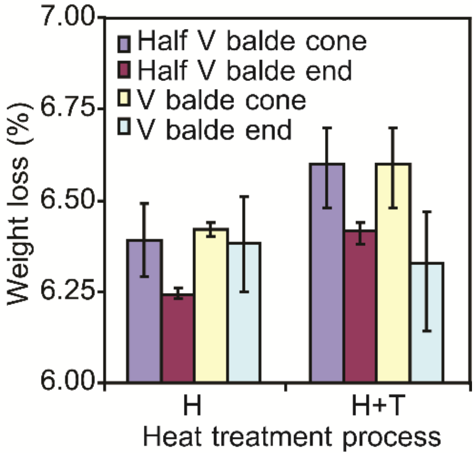

Figure 3 Relation of wear loss weight, heat treatment process and blade types

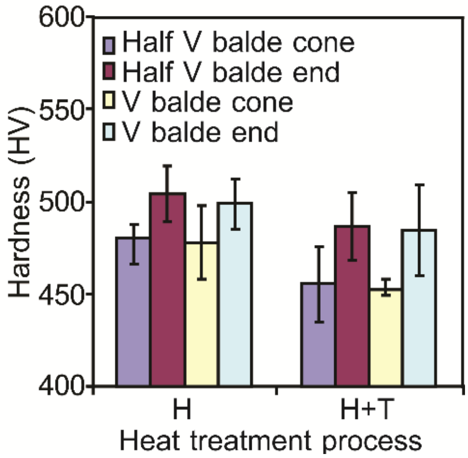

Figure 4 Relation of hardness, heat treatment process and blade type

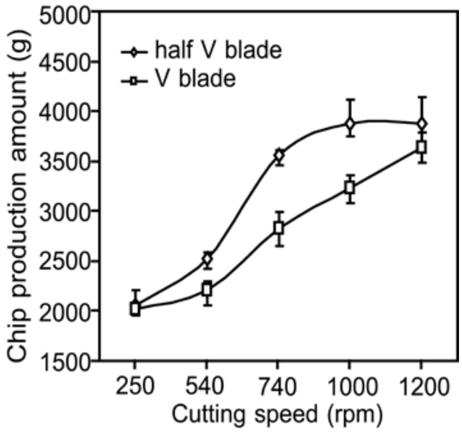

Figure 5 Relation of chip production amount and cutting speed

Figure 5 presents a result that show a relation of chip production amount and cutting speed from the testing with two blade shapes. The speed settings were 250, 540, 740, 1000 and 1200 rpm. The blade samples were made from hardening process since the previous results signified the highest hardness and wear resistance. The results indicated the relative results of chip amount with cutting speed from V shape blade. The higher in cutting speed produced the higher amount of chip production. The increase of the chip production rate with increasing the cutting speed was not cleared in this experiment but it might be due to the increase of the number of cuts. For the case of half V blade, the results were not relative. The cutting speed of 250, 540 and 740 rpm had significant change in ratio of chip amount production while 1000 rpm and 1200 rpm are produced.

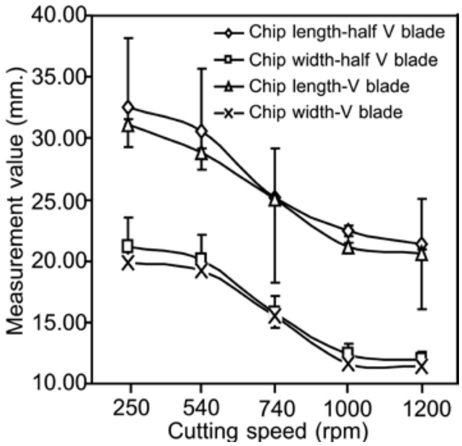

Figure 6 Relation of chip size, cutting speed, and blades

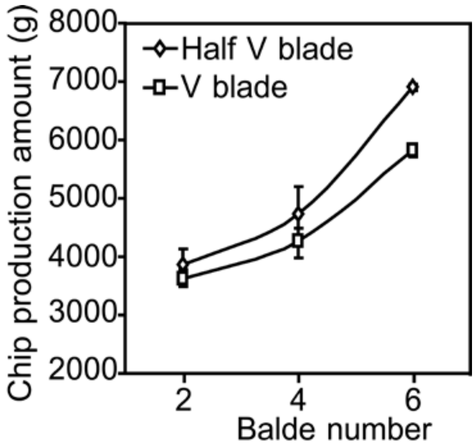

Figure 7 Relation of chip production amount, blade number

Figure 6 shows results in a relation of scrap size, cutting speed, and blades. The scrap size was determined with length and width while the goal is the smallest in both dimensions. The results indicated that the size was smaller with the higher of cutting speed. When focusing on cutting speed of 1200 rpm, the V blade samples acquire smaller size of chips as 11.46 and 20.16 mm for width and length respectively than the half V blade.

Figure 7 is the comparison results of relation between produced chip amount and a number of blades used in a chipper. The testing was based on the 1200 rpm cutting speed for best chip size produced. The results showed that half V blade yielded better in amount regardless of blade number. The more number of blade, especially 6 blades, was better than the lower number. The best result was from 6 half V shape blades for 6910 g. of palm scraps.

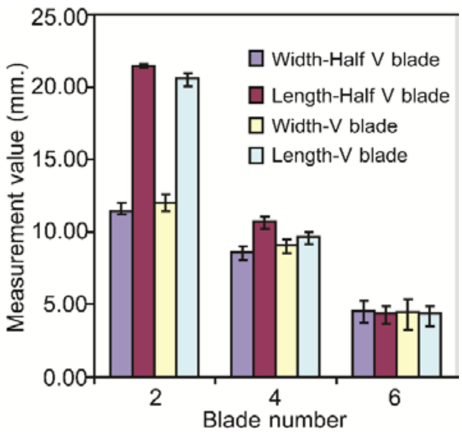

Figure 8 Relation of chip geometries and blade numbers

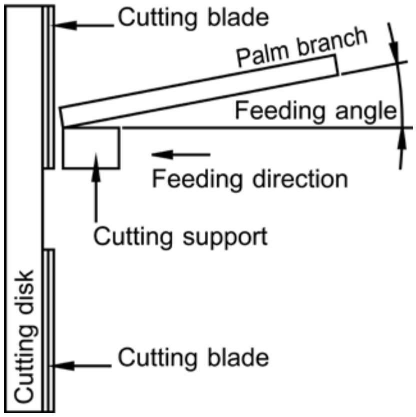

Figure 9 Feeding direction adjustment

Figure 8 displays a detail in terms of produced chip width and length for 2, 4 and 6 blade settings. The results indicated that the sizes were smaller for the higher number of blades where 6 blades produced less than 5 mm for both width and length chip size in which have been preferred for feeding and usages in a palm farming [7]. The results also are in accordance to another research results that 6 blades with highest speed produced the highest amounts with smallest size [8]. Furthermore, a higher number of blades with less cutting surface was reported to be able to cut deeper into materials resulting in faster releasing of a cut material for higher amount of scraps [9-11]. In addition, heat producing from friction in cutting process helps in deepening cut into materials although it can reduce sharpness of a cutting blade.

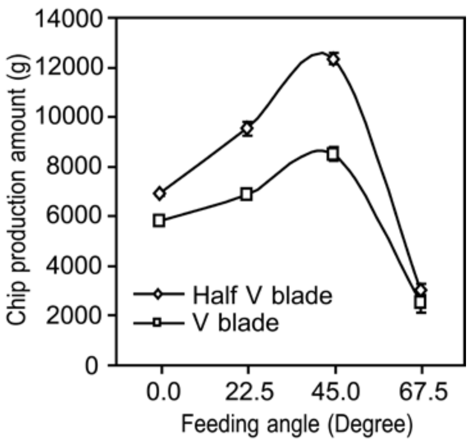

Figure 10 Relation of chip production amount and feed direction

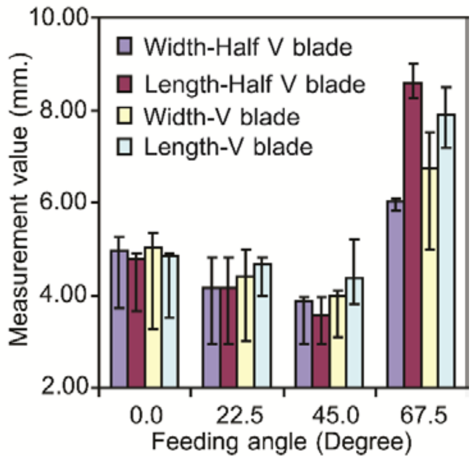

Figure 11 Relation of chip geometries and feed direction

A concept in reducing friction and cutting power by adjusting feeding angle direction was applied into experiment. The experiment was to adjusting angle of feeding as shown in Figure 9. The 0 angle was set to feeding angle in horizontal plane and parallel. Adjustment of feeding angles in the experiment were set in 4 angles from 0 to 67.5 degree. The results of chipping based on this experiment are given in Figure 10. The results from Figure 10 indicated that feeding angles directly affected an amount of chip production since there are more shear strength in cutting in which reducing resistance of the branch from the higher feeding degree [9]. Additionally, the higher of a feeding angle cause the higher pressure in feeding a palm leaf-branch. Noticeably, the feeding angle over 45° caused a flip in feeding process and resulted in reducing in chip production amount. Hence, the optimized direction result in terms of chip amount of this experiment was generated with 45° of feeding angle. In terms of width and length of chip size, comparison based on feeding angle is provided in Figure 11. The results show that 45 feeding angle degree yielded the smallest for either half V blade or V blade. The issues mentioned above from the feeding angle over 45° also caused the size to bigger than the 0 degree and were not acceptable for usage [8].

4. Conclusions

This paper presents a study result in comparison of blade shapes in vertical chip machine for palm leaf-branches. The experiments were conducted to find optimized parameters for blade development. Blade shape, cutting speed and number of blade in a chipper were studied separately to conclude an effect in amount of chip production and size of produced chips. Beside, feeding angles were tested to realize optimized setting for chipping machine. The experimental results can be concluded as follows.

- A cutting blade made of carbon steel for chipping a palm leaf-branch should be processed using hardening without tempering since tempering reduces its wear resistance and hardness.
- A half V blade is better than V blade shape for its higher in hardness as 481 HV and wear resistance with lower weight loss at 6.24%.
- A half V blade produces higher rate of chip production amount as best at cutting speed of 1,200 rpm for 3,878 grams.
- The higher number of blades assist in chipping performance, and a setting with 6 blades results in smaller size of produced scraps preferable for palm farmers.
- The practical feeding angel for chipping machine is between 0-45° while over 45° reduces cutting performance and produces chips in roughly big size.

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