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Practical Sawing Parameters for Efficient Energy Usage of Horizontal Bandsaw for Rubberwood Sawing

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ABSTRACT

Relationships between cutting energy and relevant cutting and feeding speeds for sawing of rubberwood logs with horizontal bandsaw were studied. The influences of cutting and feeding speeds of different log sizes to the energy of cutting were investigated. The diameter of the rubberwood log in the range of 5-7 inches was chosen due to the limitation of the bandsaw. The economical energy consumption of rubberwood sawing was reported for cost saving purpose. Two linear saw-blade velocity of 22 and 19.8 m/min for cutting (comparable to this bandsaw speed of 700 and 630 rpm, respectively) and three log feeding speeds of 6, 8 and 10 m/min were studied for each size range of the logs. In addition, the cutting energy of sawing was investigated for each wood board from bottom to top layer of the log (each log can obtain 4 board pieces of wood). The results showed that the lowest cutting energies of 49.18 Wh/log and 54.61 Wh/log were found at a pair of cutting speed 700 rpm and a feeding speed 8 m/min for log ranges of 5-6 inches and 6-7 inches, respectively.

1. Introduction

Rubberwood processing industries in Southern part of Thailand are the main wood board suppliers. The capacity was increased every year leading to the problem of a labor shortage. The use of automatic machines can resolve this problem.

An automatic horizontal bandsaw was then considered as a key success to solve this problem. Generally, the horizontal bandsaws were used in pinewood processing industries. It was also realized that it can be used to process the rubberwood as well. The difference in hardness of pine wood and rubberwood affects the cutting forces [1] and feeding speed [2] of sawing. This difference may influent several sawing factors such as cutting speed, feeding speed, and depth of cut, in which the process needs to be optimized. The energy cost of cutting can be affected by various factors as mentioned above. The cutting speed and feeding speed also involve the surface roughness or the wood board quality [3]. In general, the surface roughness decreased with increasing the cutting speed and decreasing the feeding speed [4-10]. The feeding speed and depth of cut also have an influence on cutting force and roughness [2,11]. In addition, good cutting speed leads to a low and minimum cutting force [4, 7, 12] which influences the power consumption. The optimum of feeding speed can be decreasing the operating time and power saving more than 30% [2]. Thus both speeds need to be optimized to get the optimal cutting energy and good quality of the wood board. The main cost of productivity in the rubberwood industry causes from power consumption and labor. Hence, the consequence of this study is leading to meet the low energy consumption and high quality productivity.

2. Materials and methods

2.1 Materials

In general, the vertical bandsaw was famously used in a rubber log sawing process. The vertical bandsaw used in this study was shown in Fig 1 (1 set of sawing used 2 vertical saws). The power of 1stand 2nd vertical bandsaw motors were 11. 2 kW and 18. 6 kW, respectively. However, the vertical bandsaw used in the industry was explored to compare only the yield with the horizontal bandsaw.

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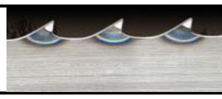
Fig. 1 Example of a vertical bandsaw

The horizontal bandsaw (Wood-Mizer HR500) with 4 cutting modules was used in this study. The power of motor in each cutting module is 11.2 kW. The 1.1 kW motor of conveyor belt was used. The profile of saw blade was shown in Table 1. This bandsaw was used to cut a log from bottom to the top layer obtaining total of 4-5 boards from each log. This study was conducted at Khao Mahachai Parawood Sawmill CO., LTD., Nakhon Si Thammarat, Thailand. The data of cutting (cutting and feeding speeds and cutting energy) of the bandsaw were observed and collected with the power monitoring device (GossenMetrawatt A2000). These obtained data were used to determine the optimal cutting and feeding speeds for the sawing process with the horizontal bandsaw. Fig. 2 showed the schematic diagram for the horizontal bandsaw and measuring device to obtain the data.

Table 1 Profile of the saw blade

	
Width (mm.)	38
Thickness (mm.)	1.14
Length (mm.)	4,010
Clearance angle (°)	10
Tooth angle (°)	50
Hook angle (°)	30
Pitch (mm.)	22.28
Gullet Depth (mm.)	6.5
Gullet area (mm.^{2})	82.75

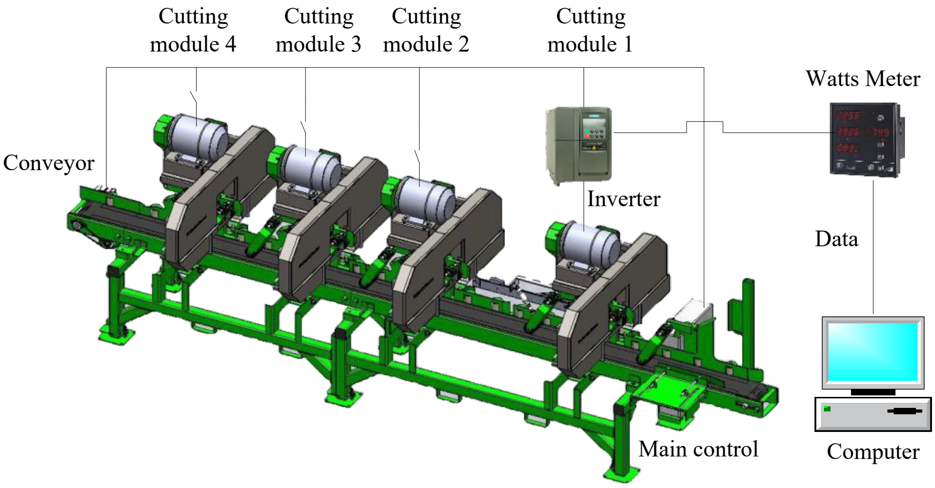


Fig. 2 Schematic diagram of the bandsaw and measuring devices

Since the limitation of horizontal bandsaw, the log size can only be fed nearly up to 8 inches (due to the interruption of saw blade supporter). The log used in this study was divided into 2 groups by diameter ranges of 5-6 inch (S1) and 6-7 inch (S2). The logs must be stored less than 3 days after cutting from the field to minimize the loss of moisture content which affects the hardness [1] and to maintain the quality of wood. Each set of the data was obtained from the same lot of logs which immediately sawed after receiving. From our further study, the moisture content changed less than 1.0% within 3 days of storing. Hence, it didn't affect the cutting energy significantly.

2.2 Methods

With this horizontal bandsaw, one side of log must be cut for obtaining smooth and flat surface for placing on the bandsaw conveyor belt tightly for feeding. The wood board sawing method used in this study is shown in Fig. 3. According to the timber size standard, the thickness of wood board chosen in this study was 2 3 ±1.00 mm (the thickness of the wood board could be slightly higher than the acceptance criteria in some cases).

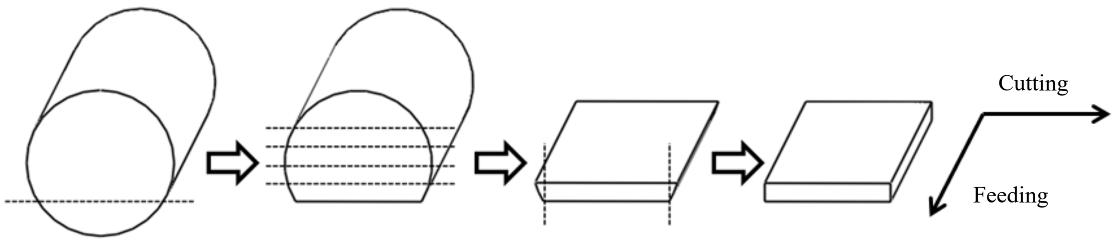


Fig. 3 Log sawing directions to wood board

2.2.1 Cutting and feeding speeds study

In this study, the cutting speed for sawing was chosen at the linear saw-blade velocity of 22 and 19.8 m/min equivalent to 70 0 rpm (maximum and normally use) and 630 rpm of pulley speeds, respectively. However, there was not reported that the lowest cutting energy can be achieved by using the maximum cutting speed for this bandsaw. Therefore, in this study another cutting speed of 630 rpm (10% decreasing from the maximum) was chosen due to the assumption of lower speed resulting to the lower energy consumption. However, if the cutting speed is too low, it will cause the jamming of the log during the sawing.

Three feeding speeds of 10 (F1), 8 (F2) and 6 (F3) m/min were compared (8 m/min is normally used in the factory). Pairs of cutting and feeding speeds were investigated to achieve the optimal conditions of lowest energy consumption, highest productivity and good surface quality. With interested factors of cutting and feeding speeds, the study was divided into 12 experiments as shown in Table 2.

Table. 2 Experiments defined

Log size	Cutting Speed	Feeding speed	code
5-6 (S1)	700 (C1)	10 (F1)	S1C1F1
		8 (F2)	S1C1F2
		6 (F3)	S1C1F3
	630 (C2)	10 (F1)	S1C2F1
		8 (F2)	S1C2F2
		6 (F3)	S1C2F3
6-7 (S2)	700 (C1)	10 (F1)	S2C1F1
		8 (F2)	S2C1F2
		6 (F3)	S2C1F3
	630 (C2)	10 (F1)	S2C2F1
		8 (F2)	S2C2F2
		6 (F3)	S2C2F3

2.2.2 Energy consumption

The cutting energy was measured from module 1 only and the total energy usage was calculated from the area under the curve of the power-time plot and data were collected and analysed while sawing. Since, the power meter can measure only a single set of continuous data, therefore, the log was only fed into module 1 and measuring the data instead of measuring data through module 2-4. Each log must be fed through the bandsaw and then that log was retaken to feed into module 1 again for another sawing board and measuring the energy usage until the last board. Sometime, the machine was jammed from the log feeding but the energy data during that time period was not to be counted and the new set of data will be replaced. In this study, the feeding energy was excluded because it was 5 times much lower than the cutting energy. The diagram of power meter is shown in Fig. 4.

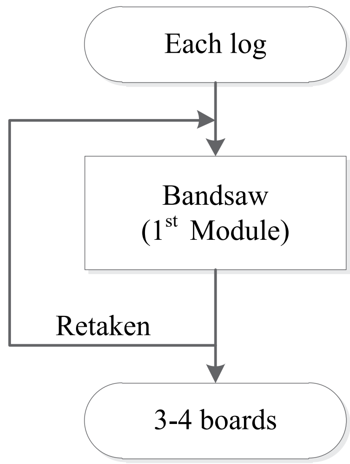


Fig. 4 Sawing process of each experiment

The data of energy usage per log was collected from the average of five logs. Each log was sawed from the bottom (layer A) and re-sawing until the top one (layer D) as shown in Fig. 5. The energy usages were reported of each layer (board) of five logs and the average-total energy of cutting of a log.

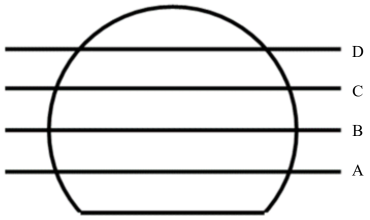


Fig. 5 Cutting layer

2.2.3 Wood board quality

In this study, the quality of a wood board was focused only on obtaining the board thickness within a range required (23±1.00 mm). The surface roughness was excluded in this study and judged by the enterprise personal for rejection. However, it was also concerned due to affecting the process yield which will decrease as a thickness increases. Thickness of each board was measured after sawing. The board thickness "T" (mm) was obtained from average of 6 point as shown in Fig. 6. And an arrow guide for the feeding direction of each log into the sawing module. The length of wood board "L" (mm) was about 1.2 meters.

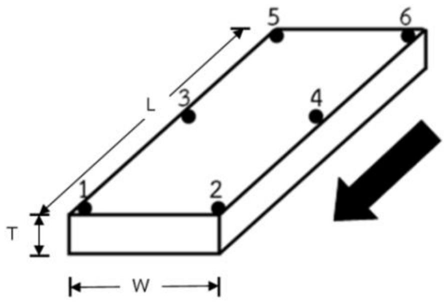


Fig. 6 Measuring locations of the board thickness

The board dimension for calculating yield of sawing board (ft^3/ tons) is given by

$$\text{Yield} = \frac{\text{W} \times \text{L} \times \text{T} \times \text{P} \times 0.02225}{\text{Log weight before sawing (tons)}} \quad (1)$$

Where in Eq.1 with each board, W (inch) is the factory required width, L (meter) is the factory required length and T (inch) is the factory required thickness. The P is the amount of board obtained.

3. Results

3.1 Effects of cutting and feeding speeds to the cutting energy of sawing

The cutting energy of sawing a wood log was obtained from the average of five logs at different pairs of the speeds. The lowest energy consumption was found at the condition of cutting speed 22 m/min (linear saw-blade velocity) and the feeding speed 8 m/min. The lowest energy consumption was 49.18 Wh/log for a log size of 5-6 inches and 54.61 Wh/log for 6-7 inches. The best condition for cutting of both log ranges (the lowest energy consumption) is C1F2 as shown in Fig. 7. The difference in cutting energy for both ranges of the best condition (C1F2) is 11.04%. However, the other conditions are less different in cutting energy than the best condition but they consume more energy, so not to be compared here.

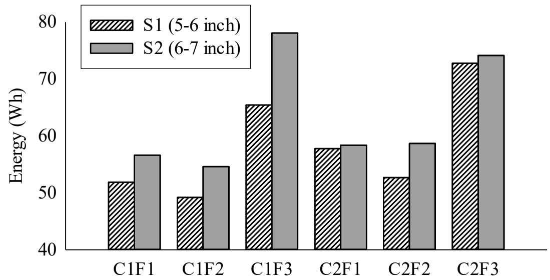


Fig. 7 Effect of log sizes on cutting energy of sawing

As shown in the Fig. 7, the cutting energy of sawing was measured and found that the cutting energy depended on both cutting and feed speeds and the size of logs. However, due to the fact that there was a small difference in both log sizes, the small difference in energy consumption was found.

Results from the previous study [2] revealed that a crucial sawdust expansion rate in the gullet and the relative sawdust volume (c, c= 1 when the dust density reaches that of the solid wood) as shown in Eq. 2 affect the minimum sawing energy effectively at the optimum log feed speed. The relative volume of sawdust in the gullet depends on both the saw blade speed (V_b), log feed speed (V_t), board width H and the blade geometries where A is the gullet area, k is saw kerf width, p is tooth pitch. Both slower and faster feed speeds than the optimum one increase the energy consumption of sawing due to the small sawdust particles and sawdust spilling out of the gullet, respectively.

$$C = \frac{V_b A k}{V_t p k H} \quad (2)$$

However in this work, both cutting and feed speeds were practically matched to observe the minimum sawing energy instead and were not considered separately. It was found that the higher of cutting speed (700 rpm) consumed less energy than the lower speed (630 rpm) mostly all of feed speed studied and the match of cutting and feed speeds definitely revealed and affected the minimum energy consumption for sawing. This matched speed might reach the optimum condition of sawing resulting of the minimum energy as mention earlier which needs to be further studied. This data was counted as a basic knowledge for sawing of rubberwood log with a bandsaw and will be useful for the industry.

3.2 Effect of area to the cutting energy

The data from Fig. 8 and 9 showed that the cutting area affected the energy usage. The higher area (width or depth) of the cut required higher of the energy. This can be confirmed by the maximum energy usage in B cut with almost highest width and the minimum energy usage in D cut of the lowest one. The cutting energy (P) was proposed [13] depending on depth of cut (or width) as in Eq.3. However, it was not found to be linear with the position of cut (A-D) reported in this study due to non-linear variation of the width.

$$P = Ckfd \quad (3)$$

Where C is Specific cutting energy, k is kerf, f is feeding speed and d is Depth of cut.

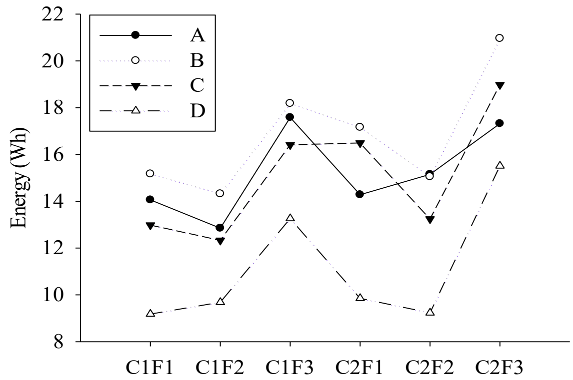


Fig. 8 The effect of area to the cutting energy (log size 5-6 inch)

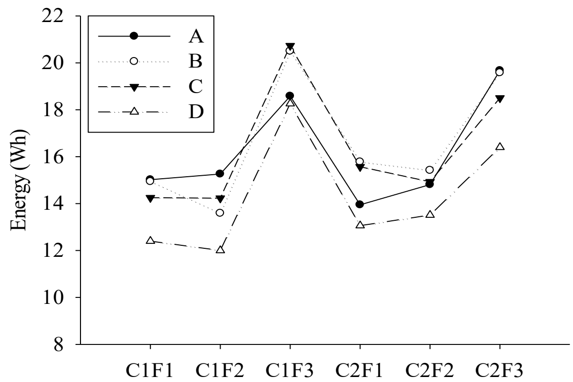


Fig. 9 The effect of area to the cutting energy (log size 6-7 inch)

3.3 Effects of cutting and feeding speeds on the board quality

The data of the board thickness of different log sizes, at various cutting and feeding speeds was shown in Fig. 10 and 11. The dash line refers to the standard size of the board studied. The results showed that all the wood boards have met the factory standard criteria (23.0 mm) and the log size (in this range of study) insignificantly affected the thickness of the wood board obtained. The result showed that the thickness of the wood board obtained from the 5-6 inch log was 23.8 mm and it was closer to the standard (23.0 mm) than the thickness of the wood board obtained from the 6-7 inch log at 24.6 mm. This was because the smaller log can be fed into the machine without interruption and resulted to the more accurate thickness.

As mentioned previously, a pair of cutting and feeding speeds may have an influence on the quality of the wood board. The board thickness of 23±1.00 mm was processed to the final board product of 12.5 mm. So, the surface quality was disregarded from this study. In this study, the quality of the board was determined by the variation of the thickness compared to the specification requirement. It was found that a feeding speed of 6 m/ min achieved in the factory required standard of thickness. This is because the low feeding speed causes the consistency and avoid the interruption of a log while sawing. However, when the feeding speed was too fast (>10m/min) the stability of the log was decreased leading to a mismatch between the cutting speed and feeding speed and resulting to the deviation from the standard.

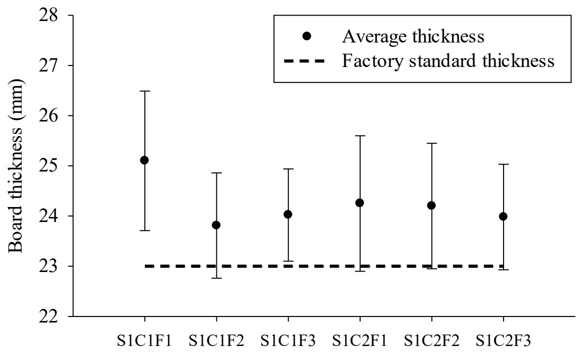


Fig. 10 The effect of cutting and feeding speeds on board thickness (size 5-6 inch)

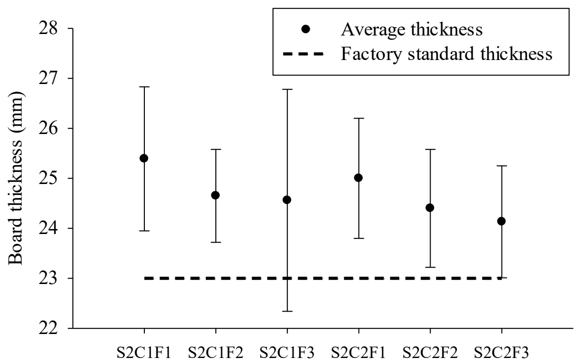


Fig. 11 The effect of cutting and feeding speeds on board thickness (size 6-7 inch)

3.4 Yielding

As shown from Fig. 12, it was found that yields from this horizontal bandsaw were 6.71 and 6.87 ft^3/ton for log ranges of 5-6 and 6-7 inches, respectively. This was higher than the yield obtained from the vertical bandsaw of 5.90 and 6.20 ft^3/ton for log ranges of 5-6 inches and 6-7 inches, respectively. It also found that the larger size of log gave a higher yield than the smaller one. Hence, it can be evidently concluded that a horizontal bandsaw gives higher yield than a vertical bandsaw.

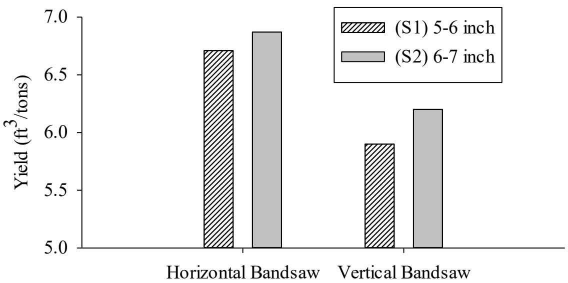


Fig. 12 Yields of horizontal and vertical bandsaws

4. Conclusion

The study found that the optimal cutting and feeding speeds for sawing of the 5-7 inches rubberwood log were 22 m/ min and 8 m/ min, respectively. These conditions gave the lowest cutting energy usage and acceptable required thickness. At a feeding speed of 8 m/ min, the horizontal bandsaw was more synchronize with the sawing conditions and eventually achieve the optimal energy conditions. The study also showed that the yield of the horizontal bandsaw is higher than the vertical bandsaws of the log range studied (5-7 inches).

These finding conditions can be applied to meet the optimal cutting and feeding speeds for the bandsaw, resulting to a high productivity and efficient energy consumption which will be useful for the industry.

5. Acknowledgement

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