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Effect of moisture to shear strength trend of Khao Dok Mali 105 stems

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Abstract. In the current rice harvesting, there is a growing popularity of combine harvesters. However, the study of the mechanical and physical properties of Thai rice stems is still limited. This research aims to study the trend of shear strength in various moisture including 50.3, 49.0, 46.6, 24.5, and 20.0 % w.b. of 3 Internodes stem of Khao Dok Mali 105. The shear strength was measured by the Lloyd LR50K Plus Materials Testing Machine. Data analysis software with NEXYGENPlus. With 1 kN of the load cell that combined with the designed shear test equipment. 30 rice stems sample tests per 1 moisture were used which divided into 3 internodes including N1 (upper internode), N2 (middle internode), and N3 (lower internode). The result shows that the shear strength was in the range 5.60-12.02, 5.93-12.96, and 6.07-14.22 MPa which is represented for N1, N2, and N3 respectively. In summary, the shear strength tended to decrease depending on the moisture of rice stems which affected to elasticity of fibers in rice stems. Therefore, this study suggested that the moisture of stems is directly affecting the shear strength.

1. Introduction

In 2018/19, Thailand has rice cultivation areas, Khao Dok Mali 105 varieties at 24.2 million hectares, yield 8.6 million tons, average value at 15,999 baht per ton [1]. Thais and foreign people have known it well and appreciate on the consumption of white jasmine rice because of the rice unique. For example, when we have to cook, the rice will be soft and smell fragrant. Moreover, after cooling down the rice, it will not freeze [2]. The aroma of jasmine rice caused by volatile substances named 2-Acetyl-1-Pyrroline (2AP), which is a volatile substance that can evaporate [3].

In the present time of rice harvest, there is growing popularity of combine harvesters because the they will decrease in a loss less than the average of manual labor at 2.84 percent, including an average of 8.86 percent of the rice crop [4]. However, the study of the mechanical and physical properties of rice stems is still minimal, which these values it is very necessary to design the equipment for the machinery that will facilitate the harvest including the selection of proper force. Due to the rice varieties of Khao Dok Mali 105, when they start to bear grains or be near to the age of harvesting, the seeds behavior will



fall easily, which can be cause of loss. Thereby, if choosing to use the cutting force is not appropriate, it may cause to increase seed loss that affected to value of rice.

The study of “Bending and Shearing Characteristics of Alfalfa Stems” from M. Nazari Galedar et al. [5] by using a double shear force method with a fixed parallel hardened steel plate of 6 mm in size between both fixed plates, there is a sliding plate freely which can be moved up and down. It has drill through the holes in all 3 plates relying on the hole size of 1.5-5 mm to accommodate the diameter of different test materials. This test device will be installed with tension/compression testing machine, in which the device uses a small load cell to test and set the sliding plate speed to $10 \text{ mm} \cdot \text{min}^{-1}$. In the test, the sample will be divided into upper, middle, and lower regions. It was found that the maximum shear strength occurred at the lower regions of 28.16 MPa at moisture content of 80%, and the lowest shear strength at the upper region was 5.98 MPa at moisture content of 10%. It is relevant to research by O’Dogherty et al. [6] finding on the shear strength of wheat stems found that Shear strength of wheatgrass is in the range of 5.4-8.5 MPa. H. Tavakoli [7] conducted research on shear strength of wheat stems and barley stems. The shear strength was in the range of 6.81-7.12 and 3.90-4.49 MPa, which belonged to of wheat stems and barley stems respectively. Moreover, “The cross-sectional area and moisture content of the plant have significant effects on the cutting power and maximum cutting power” [8, 9].

Thus, the researchers thought that finding the mechanical and physical properties of Thai rice stems is necessary in order to find the appropriate value for using the design of equipment design for Thai rice. This research aims to emphasize on the mechanical properties of rice stems. Khao Dok Mali 105 varieties, which are the study of trends for shear strength of rice stems with different moisture and cutting positions.

2. Materials and Methods

2.1. Material preparation

This research is to study the trend of rice shear strength of Khao Dok Mali 105 varieties with the factors test on different moisture and 3 Internode. Samples collected from rice fields and dried at 103°C for 24 hr [5] with a period of sampling days from harvesting until the end of the harvest season. 30 rice stems sample tests per 1 moisture were used which divided into 3 internodes including N1 (upper internode), N2 (middle internode), and N3 (lower internode). As shown in figure 1.



Figure 1. The sample distribution of rice stems is N1, N2, and N3.

2.2. Shearing test

By doing test, the shear strength of the rice will need to use a set of shear test equipment as shown in figure 2. Shear is measured by double shear machining, which consists of a parallel solid steel sheet with a thickness of 3 mm 2 sheets as a supporting base and has a sliding plate that can move up - down freely. There was punched the holes with a diameter from 2 to 7 mm and drill through the support base to support the workpiece with different diameters. The sliding plate is set at the speed $10 \text{ mm} \cdot \text{min}^{-1}$. Shear measurement by Lloyd LR50K Plus Materials Testing Machine. Made in UK. Data analysis software with NEXYGENPlus. use the load cell 1 kN and record the time and force used from the beginning until the specimen apart. The value τ_s can be calculated from equation 1 [5]:

$$\tau_s = \frac{F}{2A} \quad (1)$$

When F is the force received until the specimen apart. (N)
 A is cross-sectional area of the test specimen. (mm^2)

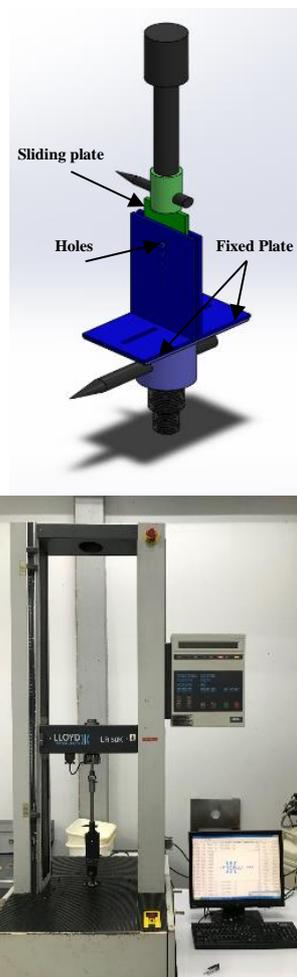


Figure 2. Apparatus for the measurement of shearing stress strength.

2.3. Analysis of variance (ANOVA)

When receiving the maximum load (N) from the test that makes the specimen apart, it will be analyzed for variance of data set to compare the differences between maximum load (N) caused by different cutting positions and moisture. The P-value is less than 0.05 that are considered statistically significant

by relying on the method Randomized Complete Block Design (RCBD) in Two-way ANOVA and Least Significant Difference (LSD).

3. Results and Discussion

3.1. Physical characteristics of rice stems

Collecting samples from rice fields at Ban Na Pieng, Samran sub-district, Mueang Khon Kaen district, Khon Kaen province, 16°31'36" N Latitude, 102°53'40" E longitude with a period of sampling days from harvesting until the end of the harvest season, there are total of 5 moisture content. The first three moisture contents are collected every other day starting from the date of harvesting, and the last two moisture contents are collected at the end of the season. It is found that the moisture of the stem is at 50.3, 49.0, 46.6, 24.5, and 20.0 % w.b. which is represented for MC1, MC2, MC3, MC4, and MC5 respectively, and the physical characteristics of the average rice stems are shown as in table 1.

Table 1. Specific physical characteristics of rice stem at different internode positions.

Parameters	N1	N2	N3
Thickness, mm	0.41±0.16	0.49±0.15	0.85±0.34
Outer diameter, mm	2.61±0.58	4.27±0.54	5.22±0.77
Inner diameter, mm	1.59±0.72	3.12±0.82	3.37±0.89
Length, mm	35.80±10.18	27.36±1.97	31.65±4.55

3.2. Results of Shearing test

According to figure 3, it is shown a graph of the relationship between Maximum load and Cross-sectional area. The different trend is divided into two groups. The first group is sample collection at the beginning of the season while the second group is the sample collection at the end of the season. The different moisture content affects to the maximum load resulting in the presented difference of force and can be divided into two trends. Therefore, it shows the relationship of equation is $y = 31.999x - 18.069$ (R-Square = 0.9886) and $y = 12.875x - 2.6625$ (R-Square = 0.9929) which is the first trend (MC1, MC2, and MC3) and the trend 2 (MC4, and MC5) respectively.

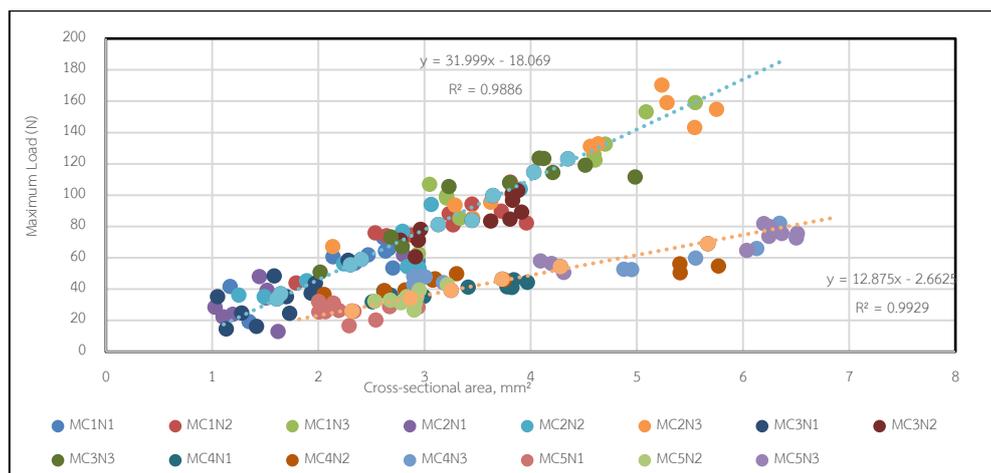


Figure 3. Maximum load versus area covered by the measurement of Shearing test.

According to figure 4, it is shown a graph of the relationship between Force and Extension, which found that in Internode N2 and N3. The graph has the behavior on the force decreasing in the extension range at a distance of about 6 mm. But Internode N1 will have a behavior of force reduced at a distance of about 4 mm. Because of the first phase, this is a resistance from the rice stem, which at this stage can

still be affected. Up to the peak of the graph is shown the point where the maximum load can be obtained before the rice plant apart resulting in a force that tends to decrease.

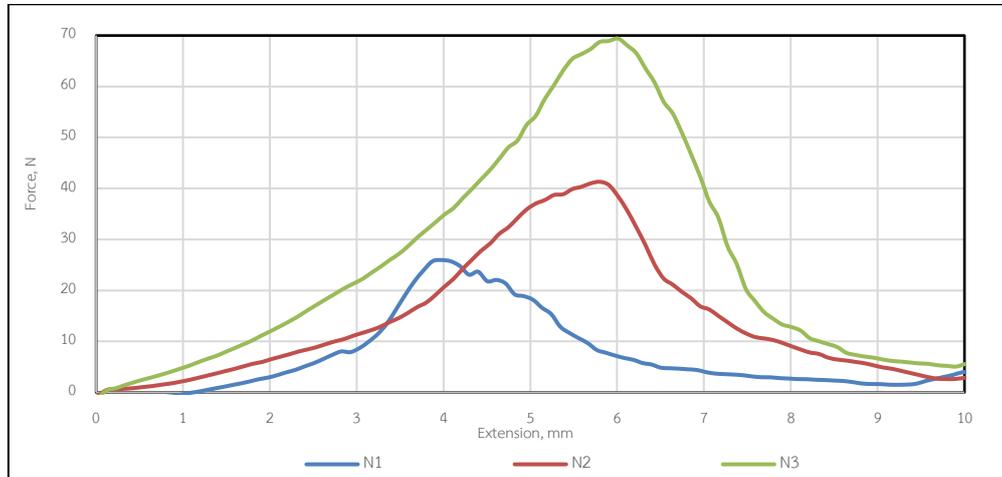


Figure 4. Force versus extension covered by the measurement of Shearing test.

According to figure 5-6 is a graph showing the relationship between Maximum load and Moisture content and Shear strength and Moisture content according to previous research by researchers [10-12]. It was found that both graphs were similar, the maximum load and shear strength being varied with moisture. Due to the higher moisture content, the fiber in the rice plant is up toughness. Therefore, requires more cutting force. And each internode, the usage on different cutting forces is sorted from descending to N3, N2, and N1 respectively. Because each Internode has different characteristics of the diameter and thickness of the rice wall are gained. From the lower part is the strongest part because it must support the weight of all rice plants. Therefore, it has a large diameter and thick wall resulting in strength and toughness that is different from the N2 and N1 parts. Therefore, it is necessary to require different forces to cut in order, which shows the relationship between the maximum load and moisture content and shear strength and moisture content as follows:

Relationship between Maximum load and Moisture content:

$$N1; \quad y = 1.8915x + 20.117 \quad (R^2 = 0.8721)$$

$$N2; \quad y = 1.2963x + 11.524 \quad (R^2 = 0.7641)$$

$$N3; \quad y = 0.4284x + 21.958 \quad (R^2 = 0.3349)$$

Relationship between Shear strength and Moisture content:

$$N1; \quad y = 0.2920x - 0.2236 \quad (R^2 = 0.9905)$$

$$N2; \quad y = 0.2395x + 0.7883 \quad (R^2 = 0.9909)$$

$$N3; \quad y = 0.2059x + 1.2341 \quad (R^2 = 0.9884)$$

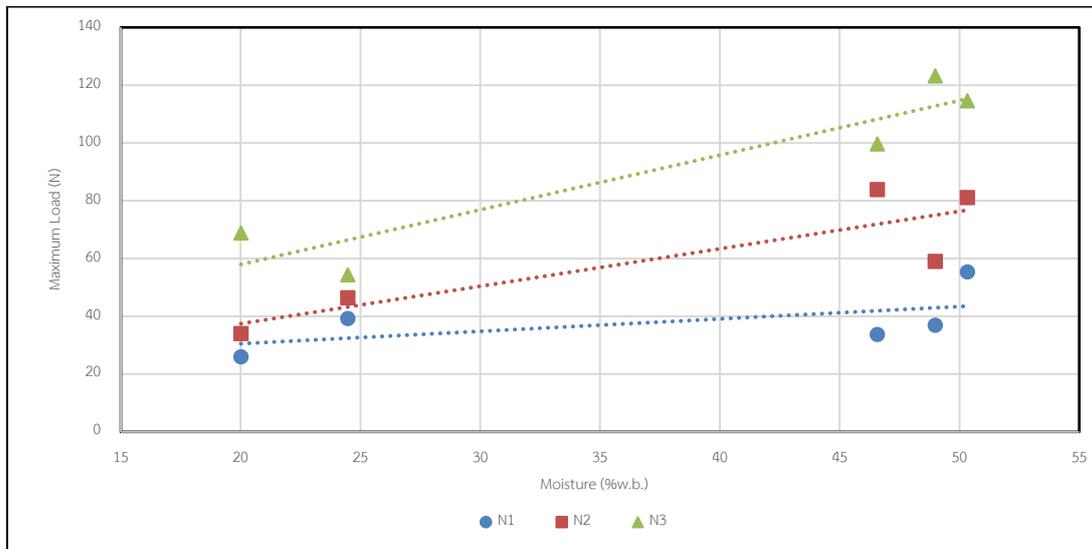


Figure 5. The changes of maximum load with moisture content according to the regions.

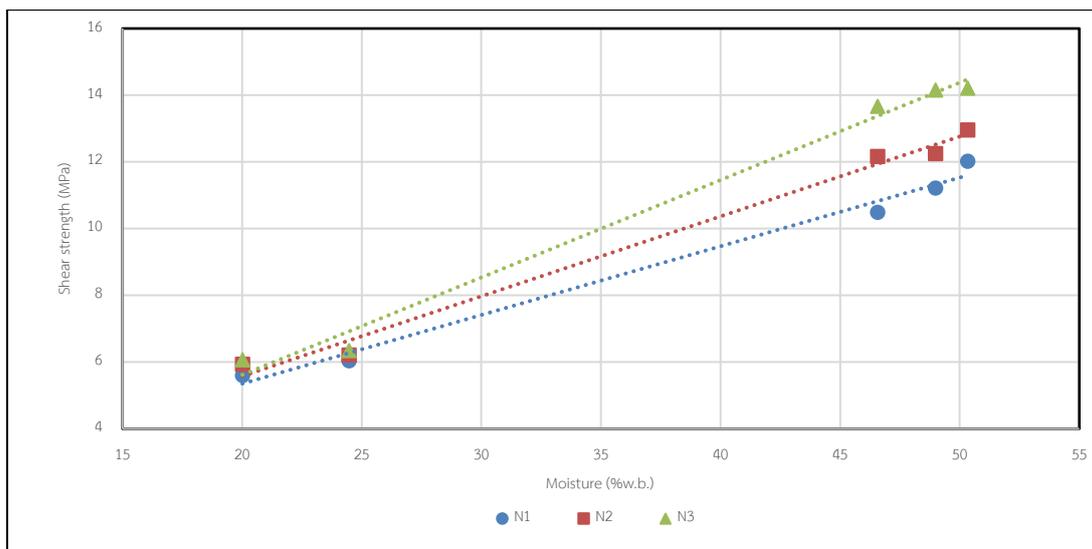


Figure 6. The changes of shearing strength with moisture content according to the regions.

3.3. Results of Analysis of variance (ANOVA)

From the test, the maximum load (N) from the test that makes the specimen apart, they will be analyzed for variance of data set to compare the differences between maximum load (N) caused by different cutting positions and moisture. The P-value less than 0.05 are considered statistically significant. The results of the statistical analysis as shown in table 2-3.

Table 2. The results of ANOVA for average maximum load (N) at different moisture content.

SOV	SS	df	MS	F	P-value	F crit
Between	19868.73	8	2483.59	7.51	2.89E-08	2.01 *
Within	44628.71	135	330.58			
Total	176157.62	149				

Table 3. The results of ANOVA are analyzed with LSD for average maximum load (N) at different moisture content. When N is internode and MC is moisture content.

	N1	N2	N3
MC1	55.40b	81.13c	114.55bc
MC2	36.94a	58.97b	123.25c
MC3	33.75a	83.87c	99.65b
MC4	39.26a	46.39ab	54.35a
MC5	25.99a	34.01a	68.84a

4. Conclusions

In this research, the effect of shear strength of rice varieties, Khao Dok Mali 105 in the moisture of stems at 50.3, 49.0, 46.6, 24.5, and 20.0 % w.b. reveals the Shear strength of 5.60-12.02, 5.93-12.96, and 6.07-14.22 MPa which is in N1, N2, and N3 respectively. By the force used to cut the rice stems, there are statistically significant differences in N2 and N3 positions at different moisture levels with a significant the P-value less than 0.05. Summary of the trend of rice stem shear strength shows that shear strength has decreased with the moisture of the rice stem because the rice plant has a lot of moisture resulting in the toughness of the fiber. Therefore, requires a lot of force to cut apart is different from the low moisture. The appearance of the rice stem is quite crisp; therefore, relying on the cutting force is not high.

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