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Parameters Affecting Fiber Quality and Productivity of Coir Spinning Machines

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ABSTRACT: To meet the demand for increasing the productivity of coir fiber products, the coir fiber automatic twisting machine has been successfully researched and manufactured. However, the output of the machine has not met the quality criteria such as coir fiber thread with an irregular diameter, uneven fiber yield production (kg/hour). Due to the influence of many factors related to the machine structure that has not been clearly defined (such as the speed of spinning, the openness of coir fiber as well as the speed of spinning of the machine), the quality and output of coir fiber is not stability. Thus, the question is to experiment to find out the factors affecting the quality and production of coir products. The paper started with the study of theoretical foundations, improved machine structure, mechanical structure, and control program to suit the production conditions of the business. The work is conducted through the experimental design table of sampling measurement, calculation, and experimental data. The calculation to find the regression equation describing the effect of the parameters related to uniformity on the product is mainly due to the workpiece speed and thread winding time and the most appropriate parameter selection of the influencing factors to adjust for the machine. Comparing the results between the product before the machine improvement and the product after the machine improvement, the criteria for evaluating the quality of coconut fiber products based on the diameter collected (mm) and the yield production will only be evaluated based on the length of coconut fiber obtained (m/min). The key content of the paper is to analyze and evaluate the factors affecting the quality and yield production of coconut fiber. They consist of two main parts: i) The first one is to analyze and evaluate the relationship between each influencing factor and yarn quality and yield. ii) The second one is to analyze and evaluate the relationship between many influencing factors and yarn quality and yield. Then is the process of improving the coir machine, the content and results of the improvement process.

KEYWORDS: quality of coir thread, machine productivity, coir spinning speed, spinning speed, thread diameter

INTRODUCTION

Climate and soil conditions in Vietnam are suitable for coconut tree growth, especially in the Mekong Delta and Central Coast regions. Currently, there are about 150000 hectares of coconut plantation, concentrated mainly in Ben Tre, Tra Vinh, Kien Giang, Ca Mau, Vinh Long, and Binh Dinh ... in which Ben Tre and Tra Vinh thrive in area and processing for export [1].

Products made from coconut are becoming more and more abundant, and businesses have taken full advantage of the processing capacity from coconuts, the main products distributed in three product groups are: dried coconuts, candies coconuts, coconut jelly, coconut products with coconut oil, desiccated coconut, coconut milk powder; Product group made from coir peat cocoa, coconut fiber, coir net, coir mats; Group of products made from coconut shell has coconut shell charcoal (sintered charcoal) and activated carbon. Besides, there are many handicraft items made from woody parts, fruits, shells, coconut leaf veins…[2][3]

Traditional coir products are ropes, twisted ropes, coir threads, brooms, brushes, doormat, floor mats, coir mattresses, rubber-coated coir sheets. From the 1980s to the 1990s, world demand dropped by almost half as Western countries turned to synthetic fibers. Since the 1990s, the demand for Indian coir products has more than doubled in the world [4]. From 2001 up to now, China has been the main market with the demand to use coir mesh to prevent erosion and coco peat instead of peat used in agriculture, gardening, vegetable, and flower growing [5][6]. The countries in developing coconut industry including the Philippines, Thailand, and Vietnam are increasingly exporting coconut fiber, which is a challenge for the two countries producing and exporting coir and the world's largest coir products: India and Sri Lanka. Every year, the export turnover of fruit and coconut products of Ben Tre in particular reaches over 70 million USD, which is a very important source of income for the province and its labor [7] .

Currently the second group of products from coconuts, which are products made from coir like coir thread, coir net, coir mats, twisted ropes, ropes ... They are usually made by hand. These products have attracted a very high export market in recent years, of which the Korean and Chinese markets are mainly. But the production activities of the people are still manual, separate, fragmented, not yet industrially concentrated [8].

The process of spinning coconut fiber is done through the stages: Harvesting coconut, transporting coconut, peeling the coconut, beating the coconut shells, and getting the thread to make the thread soft so that the thread easily sticks together when twist [9]. For a long time, the outside of the coconut was dried and beaten to create coir fiber, coir fiber used to make wires, brushes, carpets, rugs. Besides those uses, coconut fiber is now also used to make composite materials for gaskets. From the results of the research in [10], Yusoff et al. propose to make use of coir fiber to produce other garments to increase income and protect ecology.

Among the plant fibers, coconut fiber has been widely used in the development of ecological products, coconuts are concentrated in the tropical belts of Asia and the East. Coconut is one of the useful crops, the inside of the coconut provides a wide range of nutritious products, including natural coconut water for soft drinks, edible pulp, and copra (dry endosperm), which is a source of coconut oil. However, coir fiber is lightweight, strong, elastic, and highly durable and coir fiber is relatively waterproof, besides coir has low thermal conductivity. With these characteristics, more recently, coir fiber is used to produce automotive components, garden products, and many other composite products [11].

On the market, there are many different models and they are further improved productivity and quality of products as well as meet the increasing needs of export markets [12]. The machine will use only coir coconut fiber to dry and beat them, then braided them into strong coconut fibers, thereby forming products such as coir nets, coir mats ... Double yarn machines are improved from a single yarn machine to produce a more beautiful and durable product by twisting the two single yarns together. However, before operating the machine [13], it is necessary to spread coconut fiber evenly on the conveyor with a moderate length and priming a coir fiber at the beginning [14]. In the operation process of the machine, it also takes certain skilled workers to spread coir hands onto the conveyor belt to produce the right size and not break in the production process [15].

Along with the main advantages of dry coir fiber, such as low density, low cost, biodegradability, acceptable properties, less abrasion during processing, and low energy consumption in the extraction process, as well as the production of composite materials and many natural fibers, are locally available [16]. Demand for copra is large, industrial production processes, starting from milling or removing fibers from coconuts [17]. After peeling the coconut, the subsequent processes are squeezed and whisked. Manual peeling of coconut fiber is a tedious task and it can be harmful to workers. Therefore, this process needs to be performed by automatic peeling machines [18]. Romli et al. [19] have designed and developed a coir fiber copier, which can process coconut husks into useful coir products that can be marketed and used to grow orchids and other ornamental plants. The performance of the machine is limited to processing coir fiber [20].

To meet the needs of increasing productivity, the coir machine has been successfully manufactured, but its output does not meet the quality criteria of coir fiber such as diameter not equal, uneven yarn output (kg/hour). Due to the influence of many factors related to the machine structure that has not been clearly defined (such as thread speed, spinning speed of the machine), so that the quality and output of coconut fiber are not stable. Thus, the problem is to experiment to find out the factors affecting the quality and production of coir products [21].

Today, science and technology are developing faster and faster. Modern machines gradually replace human physical labor, especially in automating the production process. Therefore, the requirement is to use an automated machine in the production of coir thread and a coir machine to improve productivity and product quality as well as reduce labor. Currently, factories and enterprises have applied coconut fiber spinning machine on an industrial scale, but thread quality and productivity are still low. Thus, we can see how the production of coir thread, coir machine currently has productivity, unstable product quality, thread uniformity is not high. To meet the requirement of improving the quality of coir thread, namely the diameter of yarn more evenly but still having high productivity, we must conduct researching and improving the machine to find out the appropriate technical parameters.

The paper focuses on determining the parameters affecting the productivity and uniformity, the size of the coir thread on the double coir machine. An empirical study to evaluate the impact of 5 factors (thread length, thread rotation direction, fan speed, thread speed, thread structure of single thread, the structure of transmission mechanism and mechanical draw thread) to the quality and productivity of the coir spinning machine. Finally, a multivariate regression model was developed to determine the relationship between the conveyor speed and the batter speed to the coir fiber diameter, the relationship between the spinning speed and the beat speed to the length of coir thread.

MATERIALS AND METHODOLOGY

Coconut double coir spinning machine

Structure of the machine

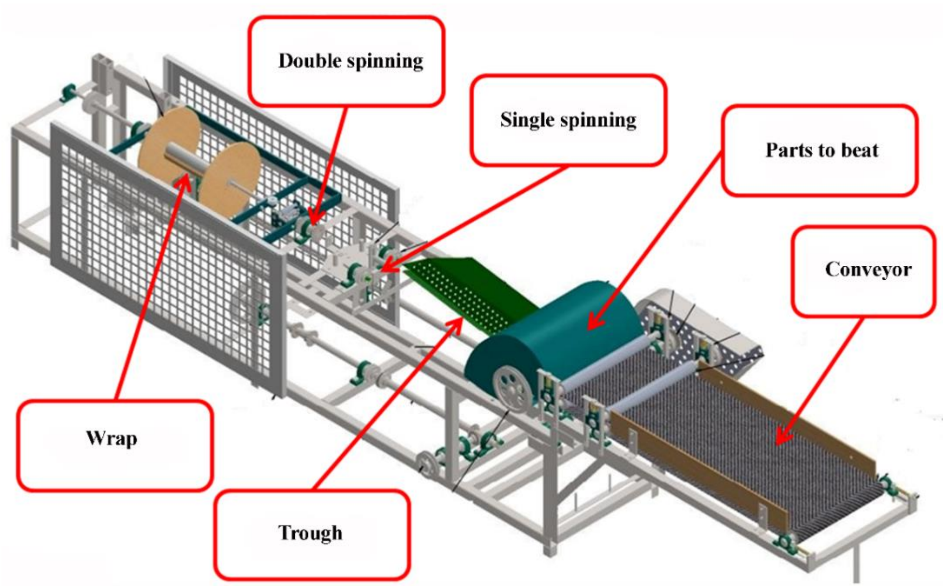


Figure 1. Machine model

The machine consists of main parts (Figure 1): 1- Conveyor: to provide coconut fiber, 2- Parts to beat: beat coconut fiber to a thread more evenly, 3- Single spinning: spinning coir into two single coir fibers, 4 - Trough: where the bait and coir coiled together, 5- Double spinning: batter two single strands into double strands, 6- Wrap: wrap coir thread into rolls.

Machine specifications

The coir thread making machine uses DK 4A80B4Y3 engine with a rated power of 1.5kW and rotation speed at 1400 rpm. The power, torque, and speed distribution on the axes are shown in Table 1.

Table 1. Distribution of power on axles

	Power (kW)	Speed (vòng/phút)	Torque (Nm)
P_{dc}	1,5	1400	10232,143
P1	1,41	280	48091,071
P2	1,32	245,5	51348,269
P3	1,24	233,3	50758,68

P4	1,166	280	39768,929
P5	1	140	68214,286
P6	0,94	279/30	32175,627
P7	0,88	186/30	45182,796
P8	0,78	186/30	40048,387
P9	0,73	186/30	37481,183
P10	0,69	279/30	23618,28
P11	0,65	93/30	66747,312
P12	0,6	30/30	191000

Changing the design of coir machine

Shorten the thread trough

The distance from the spinning tube is only 700 mm. The original trough length is 1500 mm. But the thread only drops to the trough 1200 mm from the head, will only be with very low power, will only happen because the only follow heart is mainly, only a part is only involved in the spinning process, the rest still trough [22]. After a short time, the heart only pulls a lot of coconut fiber at the same time to the thread area (700 mm from the tip) resulting in an uneven single thread [23]. Large and small sections with no spinning are forced to stop the machine to seize the new thread, some sections become big when the thread passing through the spinning thread is clogged together with a thread traction force of thread tension unit leading to a broken phenomenon [24].

The trough should be truncated. 1500 mm initially trough length is too long over the need to use. The machine size occupies a large area of the workshop (4400x600x650). The current trough length after the change is 1200 mm. Trough cut resulting in frame trimming. Reduced frame length by 250 mm. The thread needs to be stripped and removed from impurities. Lead the coir through the threshing unit and temporarily unscrew some of the seine's transmission only to harvest the coir thread of suitable quality for the shredding process [25].

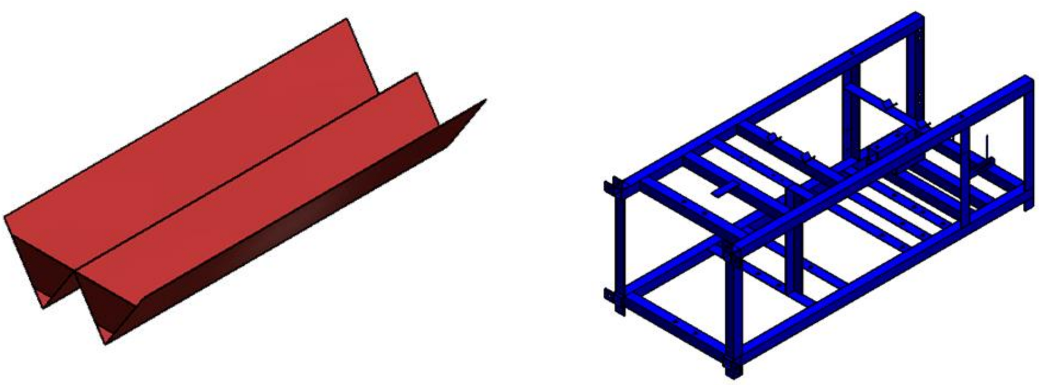
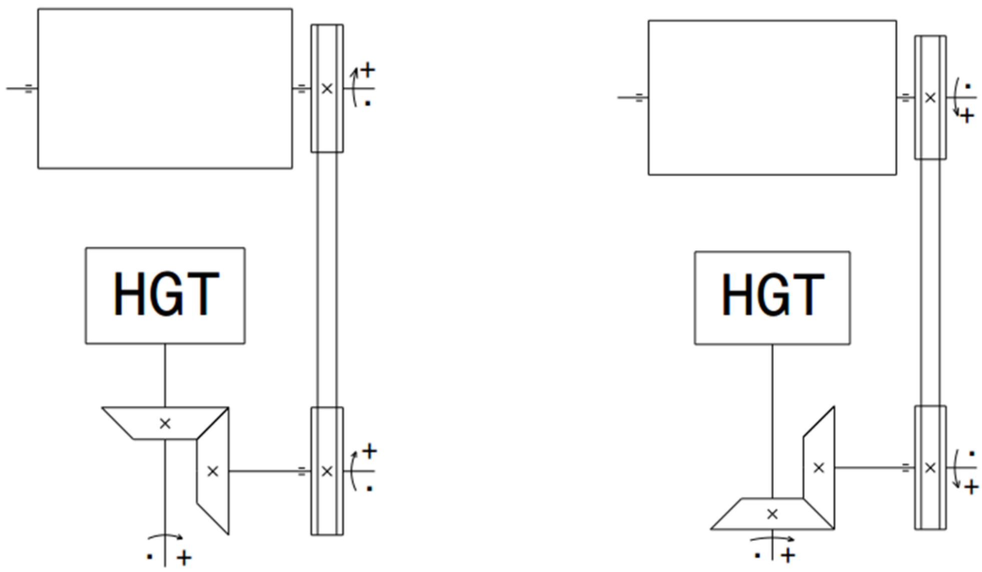


Figure 2. Thread trough after trimming - Frame after trimming

Changing the rotation of the coir fan

Through analysis and research of changing trough length. The trough is the only place where spinning is just inspired. The trough is divided into two areas, one is the spinning zone (the first 700 mm) and the other is 300 mm at the end of the trough, the length of the trough is 1200 mm. Realizing that to see just coir these two areas must intersect with each other but these two areas are separate from each other[26].

Initially, the rotation fan only turned clockwise to face down the trough, coir thread was not beaten because the stool fan only exposed to coconut fiber for a very short time, only about 300 contacts per one. rotation. Shown in Figure 3. Because both the transmission system has only one motor, it is impossible to reverse the motor rotation. So change the clutch pin position.

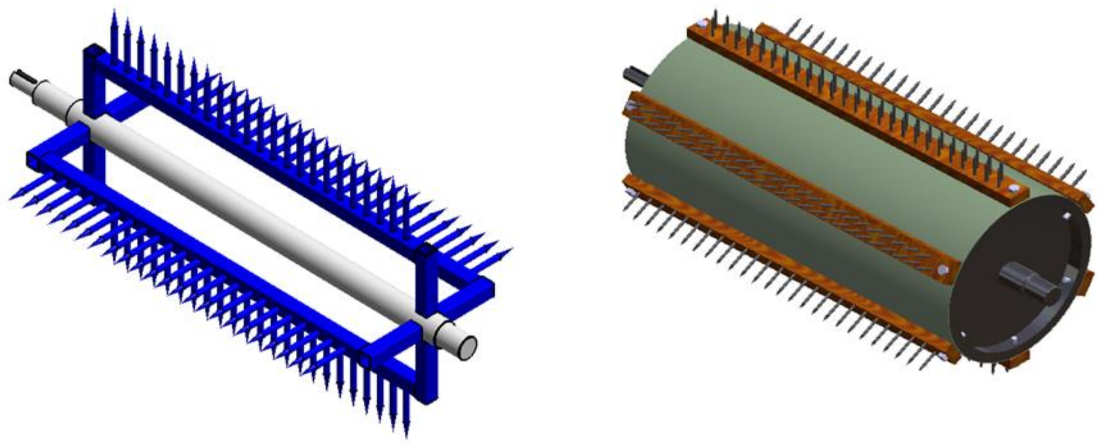


Before changing After changing

Figure 3. Dynamic diagram of a rotating fan direction

Changing the speed and design of the stool fan

The power supplied to the stool fan is not suitable for the speed of the stool fan only, specifically, the fan power is only 0.84 kW with 280 rpm. Large capacity with light load causes vibration and especially noise. Currently, when designing workshops or machinery and equipment, engineers pay great attention to the problem of noise pollution, it greatly affects the morale of work, health, or distraction for workers. As shown in Figure 3.4, the rough rotor blades with large size nails unsuitable for the coconut fiber beating stage, the nail spacing is 22 mm, so the sparse nail density along with the old rotation direction makes the inefficient part, creates many problems to be solved. Each fan segment has only 23 nails. With such a large gap that will create many gaps for the straight-through thread that has not been processed. The fan is composed of only 4 propellers, so it has low performance compared to 280 rpm. The thread coming out of the trough is not stable, because between the fan blades and the shaft is a large space, it is only possible to free fall on the entire trough surface [22]. It is necessary to create more convenient airflow for only closer contact with the top of the trough.



Before changing After changing

Figure 4. Stool fan before and after changing

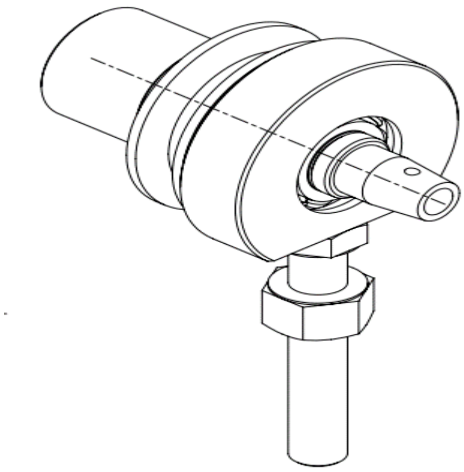
Changing the belt or bevel gear transmission. If the bevel gear transmission is changed, it will be more complicated and more expensive than the belt transmission. On the other hand, take advantage of the old belt (the old belt must have a belt stretching). The pre-shift ratio is 1: 2 at 140 rpm, causing noise and machine vibration. Need to change the transmission belt pulley from the original diameter of 80 mm to 160 mm, the transmission now has a shift ratio of 1: 1, and fan speed increased to 280 rpm. Retaining the old shaft, the new design has two flanges on both ends of the drill and a 12-hole M8 has a six-blade impeller, covering the fan body space by only 1 mm thick zinc sheet. Improving the efficiency of the stool fan just by embellishing the wind, preventing coconut fiber thread from freely passing through the space between the blades. Reducing the nail size from 8mm to 4mm, the total number of nails increased to 50 nails on a bar divided into 2 rows to increase the ability to beat and efficiency[27]. Also, increase the number of blades from 4 blades to 6 blades by the new rotation speed and conveyor speed.

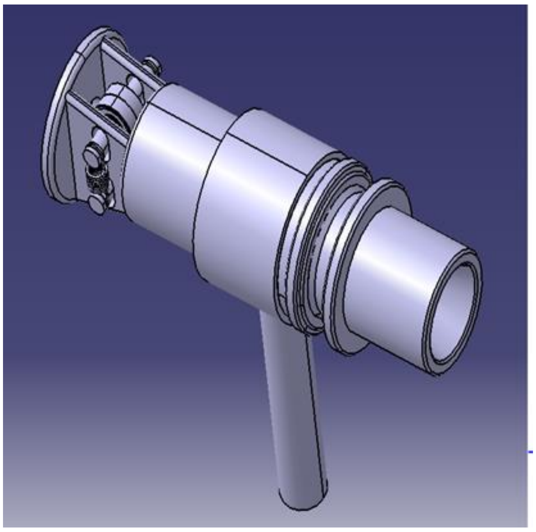
Changing the structure of the single thread spool

The hole surface is where the friction of the coir thread and spinning tube should handle the hole surface. The part that only shows the rough end of the tube is not aesthetically pleasing as well as not optimized in the design, yet to solve bad cases. As shown in the figure, the head of the machine is fitted with 2 friction barriers which are soldered to death. In the case of large size thread, the thread is stuck together with the pulling force of the thread pull mechanism.

Based on the analysis of the old thread-tube working principle to grasp some practical problems during the process of running machine testing, the discussion group came up with some solutions, then selected the necessary changes to create 3D drawings to the most satisfactory product, as shown in Figure 5.

The main changes at the beginning of the spool. The structure is changed from the small output by roller structure, the ability to go out of the head will be improved, avoid the obstruction. Besides, the flexibility of automatic resizing with a spring mechanism as shown. Detachable designed outputs are easy to disassemble for improvement and repair. The inner hole of the bobbin thread is the only surface treated by the hardening method because the inner surface of the bobbin thread is constant friction with coconut fiber with high frequency (traction force of thread pulling mechanism and rotating itself to thread).





Before changing After changing

Figure 5. The single spool tube before and after changing

Changing the gear motor at the single spinning

The spool drive is only a belt drive with a single spool with 2 spindles. As known, the transmission with the belt or chain always has a stretch and slack branch, as shown in Figure 6. Tensioner transmission efficiency is higher than that of slack branches.

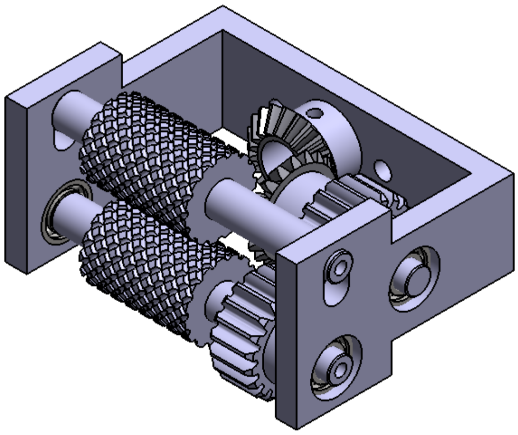
Before changing After changing

Figure 6. Drive mechanism of single pair

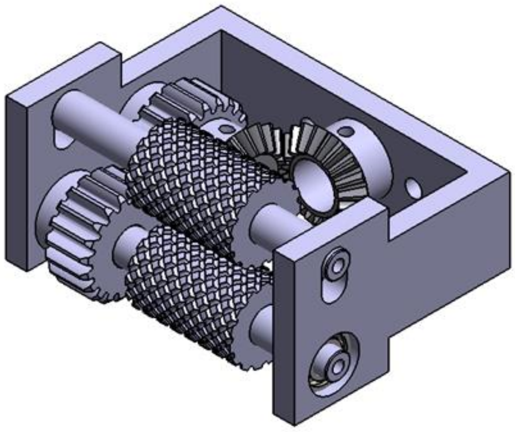
The size of the coir thread depends on many factors, one of which is the speed of the spool spin. Because the thickness of the coir thread coming out of the two spindles has a large difference in the quality of the double thread. Therefore, it is necessary to change the transmission method to adjust the rotation speed so that the two spools have the same speed. Solving the problem of quality and aesthetics of twin thread (improving product price). Change single pulley to double pulley and belt, as shown in Figure 6. Calculate belt diameter and belt length accordingly with Solidworks software. Avoid increasing the cost when installing the transmitter [28].

Changing the thread pull mechanism

Due to experiments, many times have noticed: Pointed out slowly and sometimes stuck in the place of double spin. In particular, the traction mechanism only needs to increase the thread traction force. Because the pull mechanism only turns clockwise, the thread cannot be pulled, as shown in Figure 7. The pulling shaft only requires sanding. Increase the speed of thread traction shaft. Increase jammed friction only to prevent slipping. Turn the thread pull mechanism anticlockwise so that it is only heated.



Before changing



After changing

Figure 7. 3D modeling of thread pull mechanism before and after changing

Experimental process

In this study, we conduct experiments on a coir machine which is made after adjusting the design parameters [29]. The empirical data is analyzed and processed to find an appropriate regression model describing factors that will affect the machine's productivity and coir fiber quality: 1- Speed of Conveyor (m/s): provide coir on the conveyor belt, will determine whether or not the double yarn will be uniform and the double yarn diameter, with the yarn yield. 2- Speed of the stool fan (rpm): will determine whether the single or large yarn and the twin yarn are uniforms or not. 3- The speed of the double yarn spinning head (rpm) affects the yarn diameter and yarn tightness, in addition to yarn spinning and yarn yield [30].

Experimental data was reprocessed from the raw database of more than 2000 samples (each finished of 10 cm yarn took 1 sample) and divided into 6 cases. Case 1: Conveyor speed - average diameter of coir thread. Case 2: Thread fan speed - average diameter of coir thread. Case 3: Conveyor speed and thread fan speed - the average diameter of coir thread. Case 4: Double spinning speed - the average length of coir thread. Case 5: Thread fan speed - the average length of coir thread. Case 6: Double head speed and fan speed - the average length of coir thread.

RESULTS AND DISCUSSION

Effect of conveyor speed on the quality of coconut fiber

Establishing a condition for a simple regression problem between the conveyor speed and the average diameter of coir thread, setting the dependent variable Y: average diameter (mm), independent variable X: conveyor speed (rpm). Simple regression analysis between X and Y according to the regression model of the form Y = 1 / (a + b / X) and the coefficients as Table 2 below:

Table 2. Regression model factors.

Parameters	Least-squares of estimation	Standard deviation	Statistical value P

a	0.126127	0.00157934	0.0080
b	0.441247	0.00547516	0.0079

Table 3. Variance analysis

Source	Squares sum	Df	Square expectations	F ratio	Statistical value P
Model	0.00688874	1	0.00688874	6494.84	0.0079
Residual	0.00000106065	1	0.00000106065		

Correlation coefficient = 0.999923; R^2 = 99.9846%; Standard deviation of estimate = 0.00102988. To express the relationship between the conveyor speed (X) and the average diameter (Y) of coir thread we have the following regression equation:

$$Y = \frac{1}{0.126127 + \frac{0.441247}{X}} \tag{1}$$

Because the statistical value P in Table 2 and Table 3 is less than 0.05, there is a statistical relationship between the mean diameter (Y) and the conveyor speed (X) at the 95.0% confidence level. The square root R statistic indicates that the model is accurate to 99.9846% of Y. The standard error of the estimate is 0.00102988, the smaller the value, the greater the accuracy of the problem.

Table 4. Analysis of variance with Lack-of-Fit

Source	Squares sum	Df	Square expectations	F ratio	Statistical value P
Model	0.00688874	1	0.00688874	6494.84	0.0079
Residual	0.00000106065	1	0.00000106065		
Lack-of-Fit	0.00000106065	1	0.00000106065		

The statistical value P of Table 4 is less than 0.05, so this model is perfectly suitable to describe the relationship between conveyor speed and the average diameter of the coir thread.

Table 5. Prediction values for mean diameter Y using the regression model.

Predict		The prediction limit is at 95%		Confidence limit at 90%	
X	Y	Lower bound	Upper bound	Lower bound	Upper bound
2.4	3.22602	3.0458	3.4289	3.0976	3.36555

6.18	5.06262	4.66588	5.53311	4.80642	5.34769

Among the models fitted, the Double reciprocal model has the highest square R-value with 99.9846%. This model is currently selected. It can be affirmed that the conveyor speed affects the fiber quality in general and the average diameter of coconut fiber in particular.

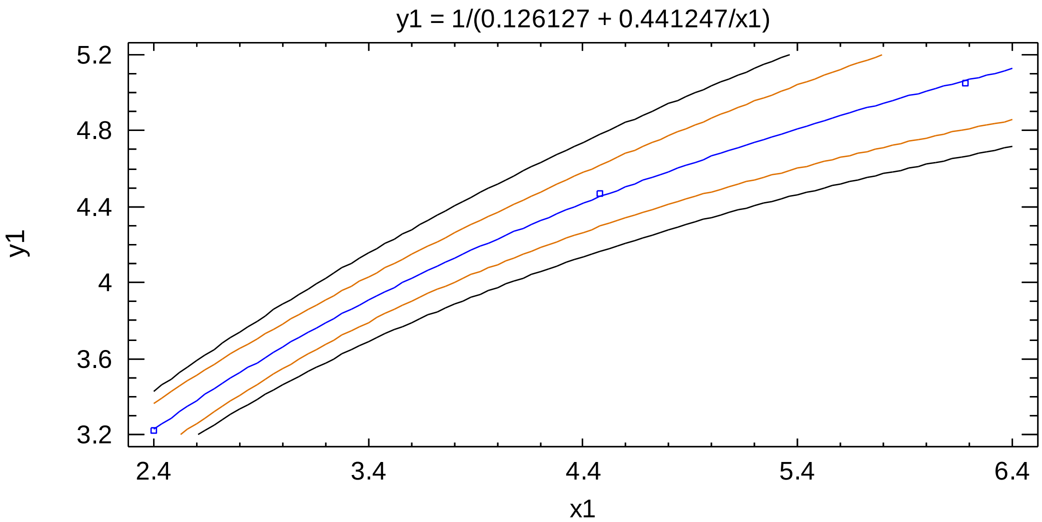


Figure 8. Double reciprocal model function graph showing the relationship of conveyor speed to the average diameter of coir thread

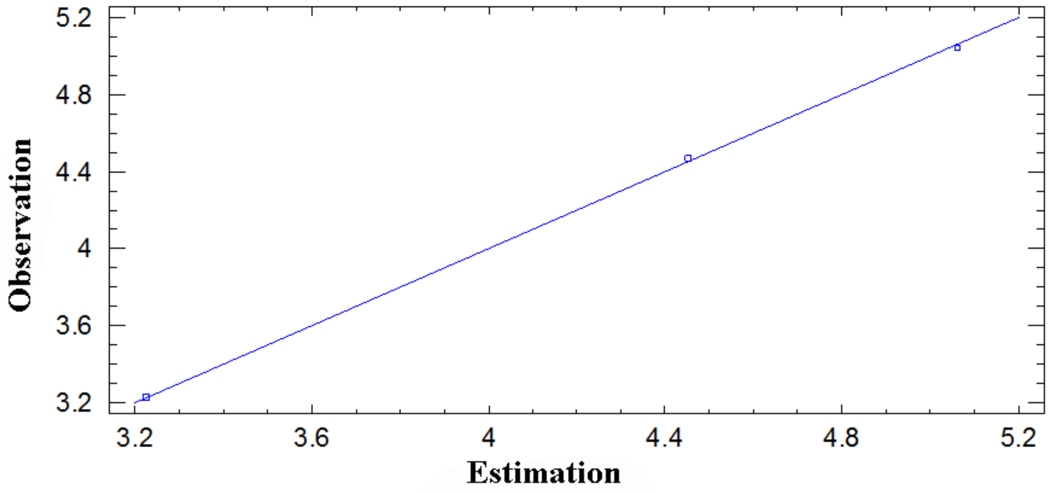


Figure 9. The diagram shows the position of the experimental points compared to the appropriate line of the average diameter of the coir thread

Effect of fan speed only on the quality of coconut fiber

Establishing a condition for a simple regression problem between the beating speed and the average diameter of coir thread, setting the dependent variable Y: average diameter (mm), independent variable X: fan speed only (rpm). Simple regression analysis between X and Y follows the regression model of the form Y = 1 / (a + b / X) coefficients as shown in Table 6.

Table 6. Regression model coefficients

Parameters	**Least-squares of estimation**	**Standard deviation**	**Statistical value P**

a	0.188585	0.0303618	0.1016
b	1.51683	8.41149	0.8864

Table 7. Analysis of variance.

Source	Squares sum	Df	Square expectations	F ratio	Statistical value P
Model	7.12125E-7	1	7.12125E-7	0.03	0.8864
Residual	0.0000218992	1	0.0000218992		

Correlation coefficient = 0.177466; R2 = 3,14942%; Standard deviation of estimate = 0.00467966. To express the relationship between the fan speed (X) and the average diameter (Y) of coir thread we have the following regression equation:

$$Y = \frac{1}{0.188585 + \frac{1.51683}{X}} \quad (2)$$

Because the P-value in Table 7 is greater than 0.05, there is no statistical relationship between the mean diameter (Y) and the beating speed (X) at the 95.0% confidence level. The square root R statistic indicates that the considered model has an appropriate level of 3,14942% compared to the variation of mean diameter (Y). The correlation coefficient is equal to 0.177466, which shows a relatively weak relationship between variables.

Table 8. Analysis of variance with Lack-of-Fit.

Source	Squares sum	Df	Square expectations	F ratio	Statistical value P
Model	7.12125E-7	1	7.12125E-7	0.03	0.8864
Residual	0.0000218992	1	0.0000218992		
Lack-of-Fit	0.0000218992	1	0.0000218992		

The statistical value P of Table 8 is greater than 0.05, this model is not suitable to describe the relationship between the beating speed and the average diameter of coconut fiber. Among the models fitted in the experimental data, the Double reciprocal model has the highest R-squared value of 3,14942%. This is the model currently selected. Because the points are farther away from the line, the model is less accurate. Study the effects of double yarn speed and coir length. So the speed of the head has little effect on the length of the coir thread.

Table 9. Predicted values of mean diameter Y using the regression model.

	Predict	The prediction limit is at 95%		Confidence limit at 90%	
X	**Y**	**Lower bound**	**Upper bound**	**Lower bound**	**Upper bound**
250.0	5.13737	3.62577	8.8105	4.00195	7.17227

311.11	5.16902	3.6592	8.79996	4.05324	7.13245

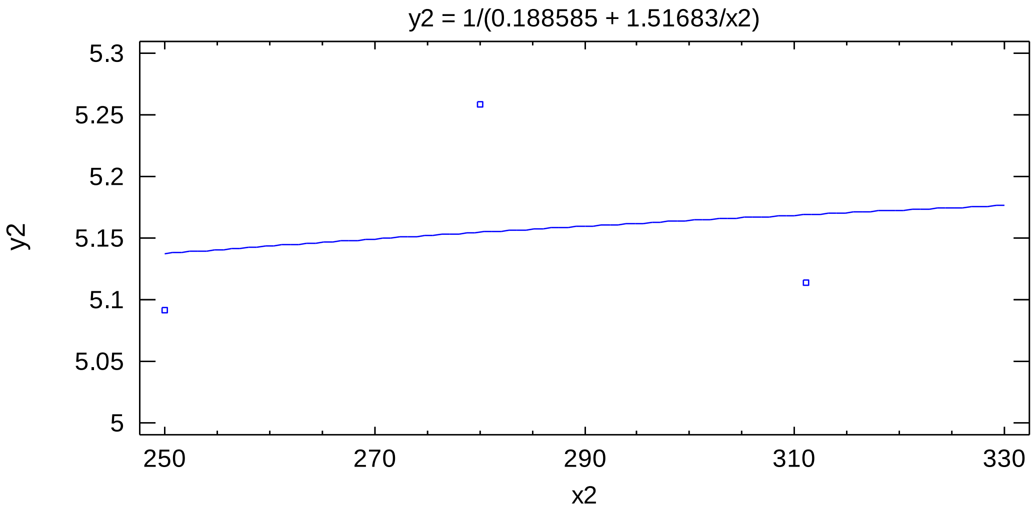


Figure 10. Graph showing the dependence of the average diameter of coir thread on the conveyor speed

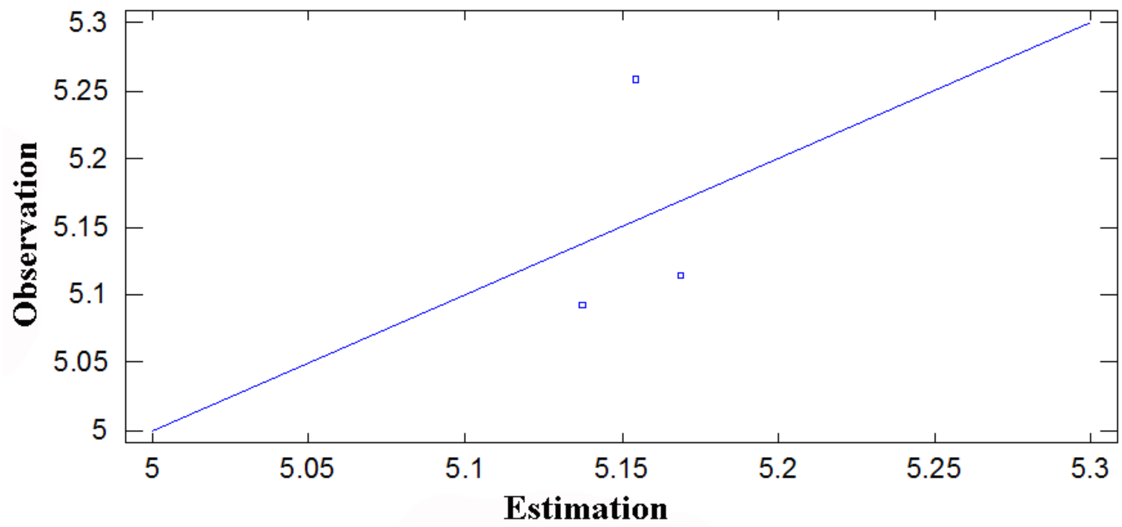


Figure 11. The graph shows the position of the experimental points compared with the appropriate line of the average diameter of the coir thread

Effect of double spinning speed on the quality of coconut fiber

Establishing the condition for a simple regression problem between the double head speed and the average length of coir thread, setting the dependent variable Y: average length (m / min), independent variable X: spinning speed level (rpm). Simple regression analysis between X and Y and the regression model has the form: Y = 1 / (a + b / X) and the coefficients as Table 10.

Table 10. The coefficients of model

Parameters	Least-squares of estimation	Standard deviation	Statistical value P
a	47.3904	2.96979	0.0398
b	-4718.62	608.288	0.0816

Table 11. Analysis of variance

Source	Squares sum	Df	Square expectations	F ratio	Statistical value P
Model	62.9875	1	62.9875	60.17	0.0816
Residual	1.04675	1	1.04675		

Correlation coefficient = -0.991793; R squared = 98.3653%; Standard deviation of estimate = 1.02311. To show the relationship between the double spinning speed (X) and the average length (Y) of coir yarn we have the following regression equation:

$$Y = \sqrt{47.3904 - \frac{4718.62}{X}} \tag{3}$$

Because the P-value in Table 10 is greater than or equal to 0.05, there is no significant statistical relationship between the average length (Y) and the double head speed (X) at a confidence level of 95, 0%, or higher. The square root R statistic indicates that the model fitted explains 98.3653% of the variation in mean length (Y). The correlation coefficient is -0.991793, which shows a relatively strong relationship between variables.

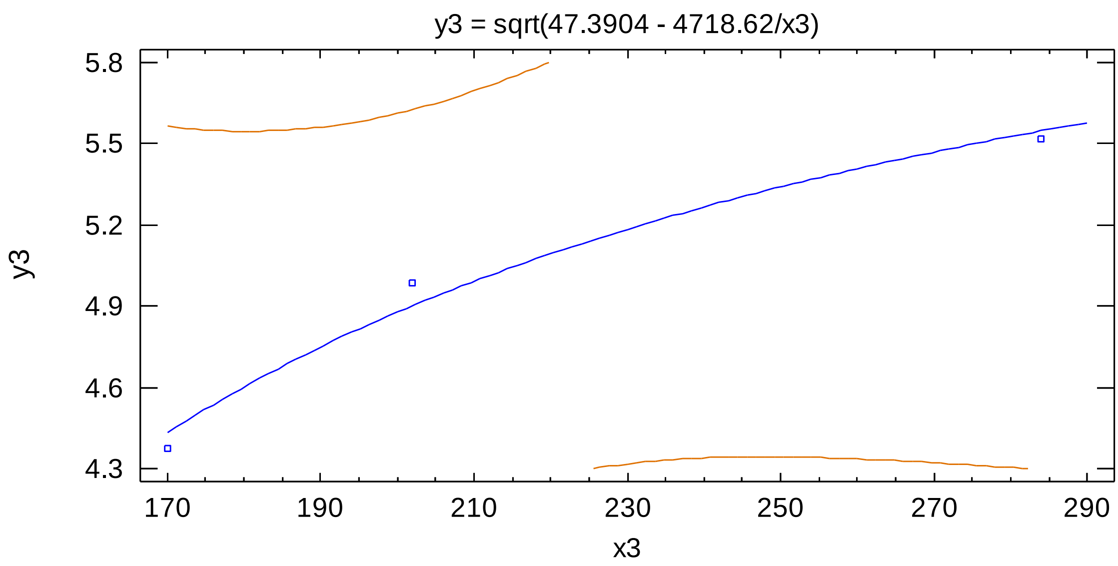


Figure 12. The graph shows the dependence of the average length of coir thread on the double top speed

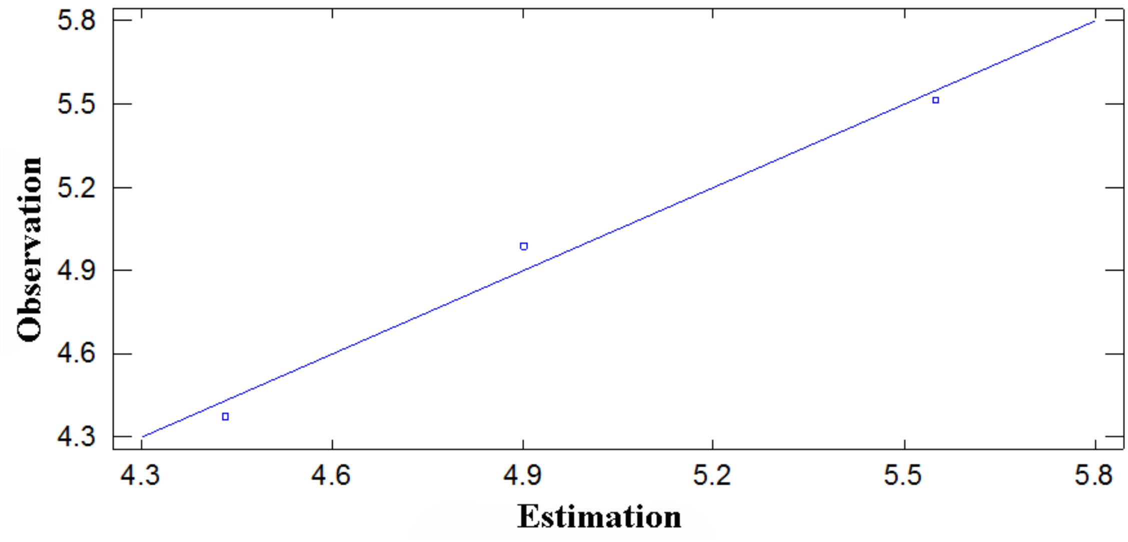


Figure 13. The graph shows the position of the experimental points compared to the appropriate line of the average length of coir thread

Among the models fitted in data, the Double reciprocal regression model has the highest R-squared value with 98.3653%. This is the model currently selected.

Table 12. Predicted values of mean diameter Y using the regression model.

Predict		The prediction limit is at 95%		Confidence limit at 90%	
X	**Y**	**Lower bound**	**Upper bound**	**Lower bound**	**Upper bound**
170.0	4.43101	1.54637	6.0726	2.88208	5.56429
284.0	5.54757	3.58713	6.97737	4.29637	6.56448

It can be seen in this model that the empirical dictionaries are close to the appropriate line, so it is confirmed that this regression model is accurate.

Effect of fan speed to the length of coconut fiber

Establishing a condition for a simple regression problem between the fan speed and the average length of coir thread, setting the dependent variable Y: average length (m / min), independent variable X: speed degree fan only (rpm). Simple regression analysis between X and Y according to the regression model has the form: Y = 1 / (a + b / X) and the coefficients as Table 13.

Table 13. Model coefficients

Parameters	Least-squares of estimation	Standard deviation	Statistical value P
a	0.218356	0.013109	0.0382
b	1.07726	3.63174	0.8164

Table 14. Analysis of variances

Source	Squares sum	Df	Square expectations	F ratio	Statistical value P
Model	3.5919E-7	1	3.5919E-7	0.09	0.8164
Residual	0.00000408236	1	0.00000408236		

Correlation coefficient = 0.284377; R^2= 8.08705%; Standard deviation of estimate = 0.00202048. To express the relationship between the fan speed (X) and the average length (Y) of coir thread we have the regression equation:

$$Y = \frac{1}{0.218356 + \frac{1.07726}{X}} \tag{4}$$

Because the P-value in Table 13 is greater than 0.05, there is no statistical relationship between the average length (Y) and the fan speed only (X) at the 95.0% confidence level.

The square root R statistic indicates that the model fits only at 8.08705% with the variation in mean length (Y). The correlation coefficient is equal to 0.284377, which shows a relatively weak relationship between variables.

Table 15. Analysis of variance with Lack-of-Fit.

Source	Squares sum	Df	Square expectations	F ratio	Statistical value P
Model	3.5919E-7	1	3.5919E-7	0.09	0.8164
Residual	0.00000408236	1	0.00000408236		
Lack-of-Fit	0.00000408236	1	0.00000408236		

Table 16. Y predicted average length values using the regression model.

	Predict	The prediction limit is at 95%		Confidence limit at 90%	
X	**Y**	**Lower bound**	**Upper bound**	**Lower bound**	**Upper bound**
250.0	4.49105	3.88044	5.32972	4.05664	5.02966
311.11	4.50819	3.90194	5.33749	4.08476	5.02956

Table 15 is larger than 0.05, this model is not suitable to describe the relationship between thread fan speed (X) and average length (Y) of coir thread. Among the models fitted in the experimental data, the Double reciprocal model has the highest R-squared value with 8.08705%. This is the model currently selected.

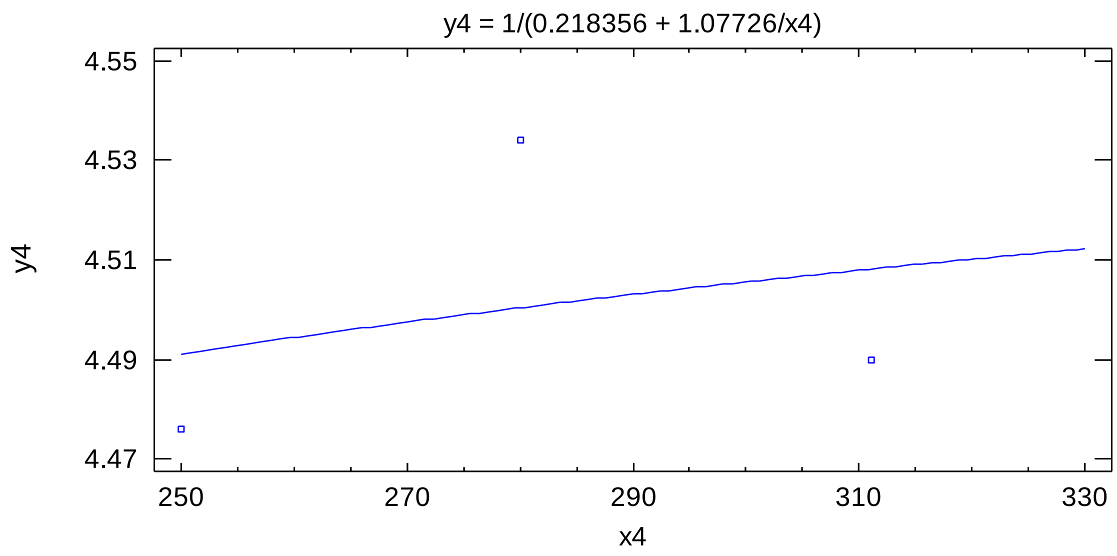


Figure 14. The graph shows the dependence of the average length of coir thread on the thread fan speed.

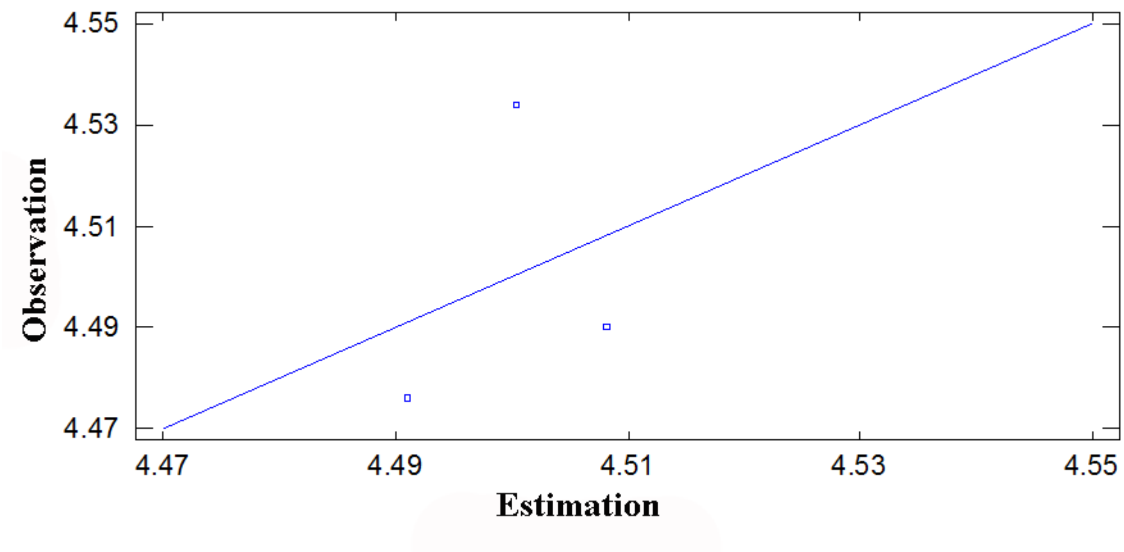


Figure 15. Graph showing the position of the experimental points relative to the appropriate line.

It can be seen in this model that the experimental points are far from the appropriate line, so it is confirmed that this regression model is inaccurate, and the data show that this is the best model. It is therefore concluded that the thread fan speed does not affect the thread length.

Effect of conveyor speed and fan speed on the quality of coconut fiber

Establishing conditions for multivariate regression problems between conveyor speed, fan speed, and coir thread quality, setting dependent variable Y: average diameter (mm), independent variable X1: speed Conveyor degree (rpm), and X2: thread speed fan only (rpm). Analysis 1: Analysis selected linear regression model with dependent variable Y, independent variable A = X1, and B = X2. There are a total of nine cases, of which four are appropriate. In Table 17, the models show the maximum adjusted values of R squared. The square root R statistics that adjust the rate of variation in y12 are explained by the model. The larger values of R squared are adjusted to correspond to the smaller values of the mean square error. Up to 5 models in each subset from 0 to 2 variables are displayed. The best model contains only one variable (x1).

Table 17. Empirical results between the conveyor speed, fan speed and thread quality of coconut fiber

X1	X2	Y
2.4	250	2.938
4.48	250	4.434
6.18	250	5.044
2.4	280	2.926
4.48	280	4.636
6.18	280	4.994
2.4	311.11	3.288
4.48	311.11	4.62
6.18	311.11	5.072

Table 18. Table of models with R largest squares in analysis 1

MSE	R squares	R squared adjustment	Cp	Variables
0.066322	92.933	91.9234	1.77875	A
0.0684866	93.7448	91.6598	3.0	AB
0.821163	12.5	0.0	90.1422	B
0.821163	0.0	0.0	88.921	

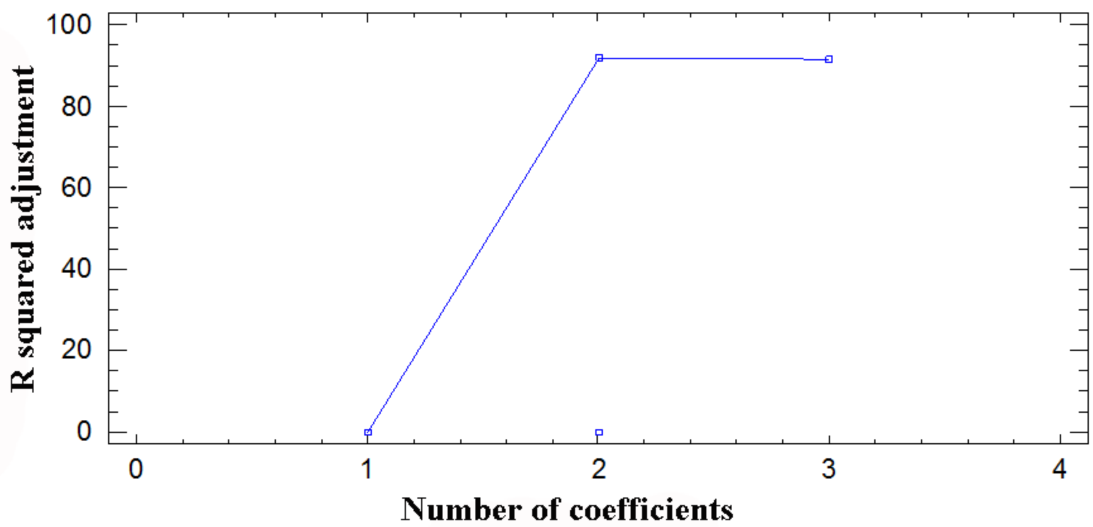


Figure 16. The degree of correlation between variables

Analysis 2: Analysis and selection of non-linear regression model with dependent variables log (Y), independent variables A = log (X1), and B = log (X2). There are 4 suitable cases.

Table 19. Table of models with R largest squares in analysis 2

MSE	R squares	R squared adjustment	Cp	Variables
0.00267078	96.324	95.0987	3.0	AB
0.00288325	95.3702	94.7088	2.55687	A
0.0544915	12.5	0.0	156.666	B
0.0544915	0.0	0.0	156.222	

Table 19 shows the models giving the maximum adjusted values of R squared. The adjusted R-square statistic measuring the rate of change in log (Y) is explained according to the model. The larger values of R squared are adjusted to correspond to the smaller values of the mean square error. Up to 5 models in each subset from 0 to 2 variables are displayed. The best model contains 2 variables, log (X1), and log (X2).

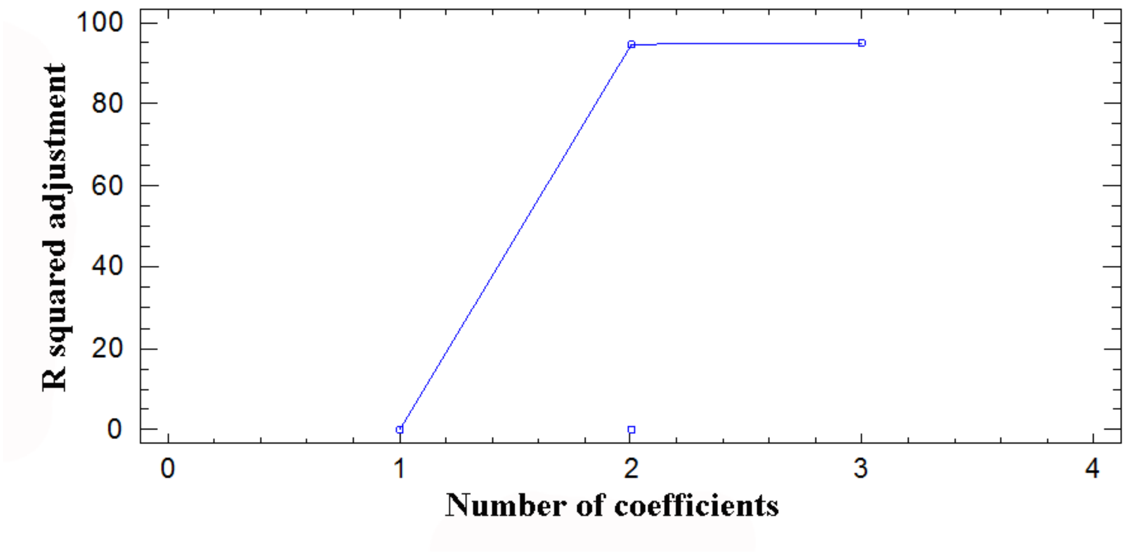


Figure 17. Correlation level between variables.

Analysis 3: Multivariate regression analysis with dependent variable sqrt (Y), with two independent variables, namely 1 / X1 and 1 / (X1 * X2)

Table 20. Parameter table of the regression model of conveyor speed, spin speed, and average fiber diameter of coconut fiber

Parameters	Estimate	Standard deviation	Statistical value P
Constant	2.56853	0.0211381	0.0000
1/x1	-1.03811	0.317382	0.0170

1/(x1*(x2))	-259.182	85.8931	0.0235

Table 21. Table of variance analysis.

Source	Squares sum	Df	Square expectations	F ratio	Statistical value P
Model	0.417099	2	0.208549	365.88	0.0000
Residual	0.00342001	6	0.000570001		

R squared = 99.1867%; Standard deviation of wage estimate = 0.0238747; Average absolute deviation = 0.0157413; Durbin-Watson statistics = 3.20286 (P = 0.9600).

The results of the multivariate regression model are suitable to describe the relationship between (Y: mean diameter) and 2 independent variables (X1: conveyor speed and X2: fan speed only). The equation has the form:

$$\sqrt{Y} = 2.56853 - \frac{1.03811}{X_1} - \frac{259.182}{X_1 X_2} \quad (5)$$

Because the P-value in Table 20 is less than 0.05, there is a statistical relationship between the variables at the 95.0% confidence level. The R-squared statistic indicates that the model was equipped to explain 99.867% of the variance of sqrt (Y). The standard deviation of the estimate shows that the standard deviation of the estimation problem is 0.0238747. Because the Durbin-Watson test statistic P-value is greater than 0.05, there is no sign of serial autocorrelation in the residuals at the 95.0% confidence level. Because the experimental points are located close to the appropriate line, it is confirmed that the regression model as above is appropriate.

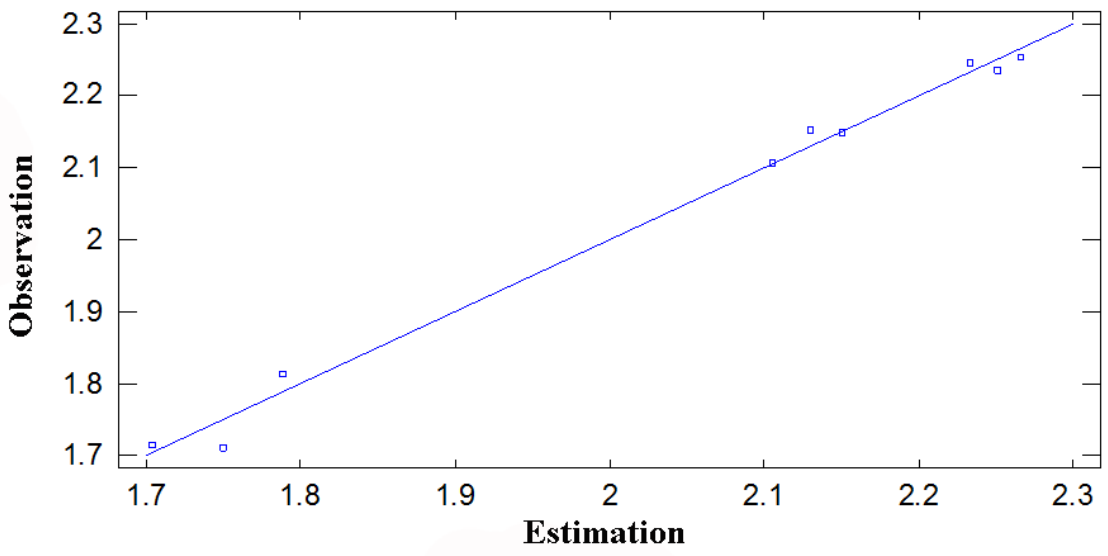


Figure 18. Graph showing the position of the experimental points relative to the appropriate line.

The effect of double head speed and fan speed on the length of coir thread

Set up conditions for multivariate regression problems between double head speed, fan speed, and coir thread length, set dependent variable Y: average length (m / min), independent variable X1: dual head speed (rpm), and X2: dual fan speed (rpm). Analysis 1: Analysis selected regression model with dependent variable Y, independent variable A = X1 and B = X2. There are a total of 9 cases, of which 4 are appropriate.

Table 22. Experimental results on the relationship between double head speed, fan speed, and thread length

X1	X2	Y
250	4.524	170
250	5.034	202
250	5.5	284
280	4.402	170
280	5.054	202
280	5.44	284
311.11	4.47	170
311.11	5.104	202
311.11	5.514	284

Table 23. Table of models with R largest squares in analysis 1

MSE	R squares	R squared adjustment	Cp	Variables
0.066322	92.933	91.9234	1.77875	A
0.0684866	93.7448	91.6598	3.0	AB
0.821163	12.5	0.0	90.1422	B
0.821163	0.0	0.0	88.921	

In Table 23, the models show the maximum adjusted values of R squared. The square root R statistics that adjust the rate of variation in Y are explained by the model. The larger values of R squared are adjusted to correspond to the smaller values of the mean square error. Up to 5 models in each subset from 0 to 2 variables are displayed. The best model contains only one variable (X1). Analysis 2: Analysis selected linear regression model with dependent variable log (Y), independent variable A = log (X1) and B = log (X2). There are a total of 9 cases, of which 4 are appropriate.

Table 24. Table of models with the largest R squared in analysis 2.

MSE	R squares	R squared adjustment	Cp	Variables
0.00267078	96.324	95.0987	3.0	AB
0.00288325	95.3702	94.7088	2.55687	A

0.0544915	12.5	0.0	156.666	B
0.0544915	0.0	0.0	156.222	

Table 24 shows the models giving the maximum adjusted values of R squared. The adjusted R-square statistic measuring the rate of change in log (Y) is explained according to the model. The larger values of R squared are adjusted to correspond to the smaller values of the mean square error. Up to 5 models in each subset from 0 to 2 variables are displayed. The best model contains 2 variables, log (X1), and log (X2). Analysis 3: Analysis selected nonlinear regression model with dependent variable Y, independent variable A = X1, and B = X2. There are a total of nine cases, of which four are appropriate. Analysis 4: Multivariate regression analysis with the dependent variable (Y) ^ 2, setting variable X1 * log (X2) and 1 / (X1 ^ 2)

Table 25. Table of models with R largest squares in analysis 3.

MSE	R squares	R squared adjustment	Cp	Variables
0.066322	92.933	91.9234	1.77875	A
0.0684866	93.7448	91.6598	3.0	AB
0.821163	12.5	0.0	90.1422	B
0.821163	0.0	0.0	88.921	

Table 26. Parameter table of multivariate regression functions.

Parameters	Estimate	Standard deviation	Statistical value P
Constants	15.3352	3.85956	0.0073
X1*log(X2)	0.335264	0.108871	0.0217
1/(X1^2)	-60.6125	14.6774	0.0061

Table 27. Analysis table of variance.

Source	Squares sum	Df	Square expectations	F ratio	Statistical value P
Model	410.747	2	205.374	257.38	0.0000
Residual	4.78766	6	0.797943		

R squared = 98.8478%; Standard deviation of wage estimate = 0.893277; Durbin-Watson statistics = 2.26158 (P = 0.7463). The results of the multivariate regression model are suitable to describe the relationship between (Y: mean length) and 2 independent variables (X1: double head speed and X2: dual fan speed). The equation has the form:

$$Y^2 = 15.3352 + 0.335264X_1 \log X_2 - \frac{60.6125}{X_1^2} \quad (6)$$

Because the P-value in Table 26 is less than 0.05, there is a statistical relationship between the variables at the 95.0% confidence level. The square root R statistic indicates that the model was suitable at 98.8478% compared to the variation in (Y) ^ 2. The standard deviation of the estimate shows that the standard deviation of the estimated problem is 0.893277. Because the Durbin-Watson test statistic P-value is greater than 0.05, there is no sign of serial autocorrelation in the residuals at the 95.0% confidence level.

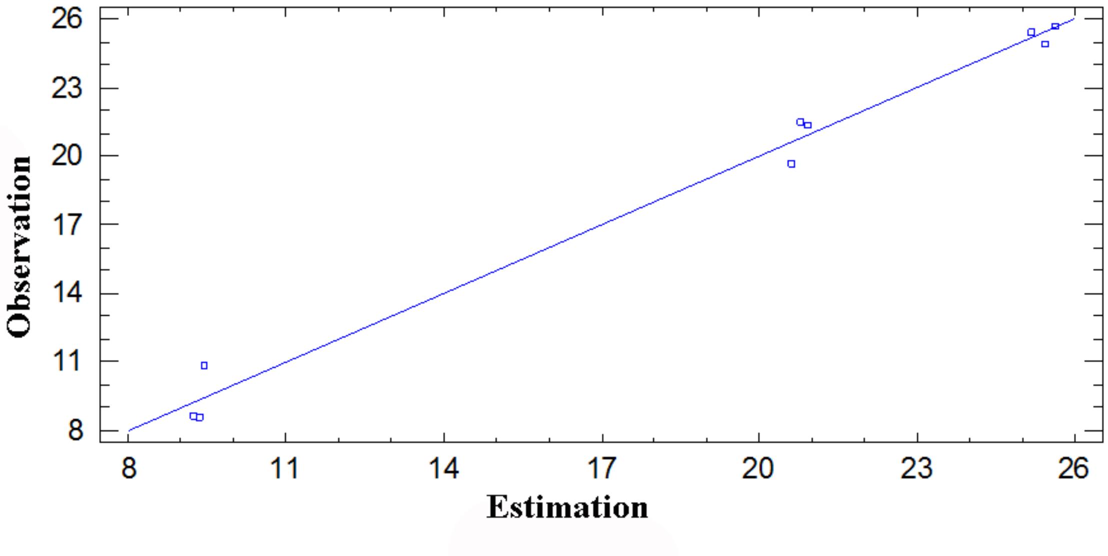


Figure 19. Graph showing the position of the experimental points compared to the appropriate length of coconut fiber.

Because the experimental points are located close to the appropriate line, it is confirmed that the regression model as above is appropriate. From the analysis of the influence of factors affecting yarn quality, the results showed that the conveyor speed has a great influence on the diameter of coconut fiber and the double speed has a great impact on the fiber length. The beaten speed has little effect on the quality of coir thread. Besides, the relationship between the conveyor speed and the threshing speed to the diameter of the coir thread is described through equation (5), the relationship between the double speed and the threshing speed to the thread length. Coconut fiber is described through equation (6).

The results showed that, before changing the conveyor speed coefficients, the fan speed and the twin head speed, the quality of coir thread was not stable, the diameter of small and irregular fibers fluctuated in the range from 1mm to more than 10mm, or broken at the end only during production. The average length of 4.67 m / minute. After changing the conveyor speed coefficients, thread fan speed and double head speed, the coir thread products are more even, the line ranges from 4mm to 6mm. No more thread breakage at the beginning of the double spinning during operation. And afternoon yield 4.82 m / min.

CONCLUSIONS

Through empirical research, the parameters affecting the quality and production of coir thread shows: The relationship between conveyor speed and the average diameter of the coir thread is proportional. That is, when increasing the speed of conveyor, the diameter of coir thread will increase, we can rely on the conveyor speed or in other words, the embryonic speed to increase or decrease the diameter of coir thread as required. The relationship between the double speed factor and coir fiber length is proportional. When increasing the double s head, the coir production increase.

Although the beaten speed does not affect the quality of coir thread, to get the best quality coconut fiber thread, it is necessary to consider the above factors to formulate the multivariate regression equation. It can be calculated backward to find the optimal parameters for the machine, the result of the improvement shows that the yarn quality has improved much compared to before the machine improvement. Specifically, the diameter of coconut fiber after improvement ranges from 4mm to 6mm, while the diameter of coconut fiber before improving the machine is uneven, ranging from 1mm to more than 10mm. Besides, the output of coconut fiber after improving the machine also increased by 0.15m / min compared to the time without improvement. Together with that, several conditions were found to bind between the following speed factors: (1) The lap speed must be greater than the double yarn spinning speed to create the spinning force. If the pulling force is not enough, then the double thread will get big and jam the thread where the head will double and break the thread. (2) The double spinning speed must always be less than the single spinning speed. Because the twin head speed needs to be fast to chop the twin yarn.

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