A STATISTICAL ANALYSIS OF SISAL, NYLON AND RUBBER FOR A DRYING LINE.

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Abstract

This project investigated the application of different materials as drying lines. It analyzed three types of ropes: rubber, nylon and sisal, to identify which of them would be best for a dry line using statistical analysis. It primarily focuses on the experimental data on the force, displacement, tensile strength and elastic modulus of the rope samples obtained using smart technological devices, to draw a conclusion on which one has the least expansion and the highest tensile strength. The data is collected with modern technological tools such as Pasco testing machine and analyzed using MATLAB and Microsoft Excel. The result of the statistical analysis obtained includes Sisal with a tensile strength of $8.46 \times 10^7 Psi$ standard deviation and error of 31.7±15.8, followed by nylon $1.407 \times 10^7 Psi$ and 5.0±2.5, and Rubber with $5.32 \times 10^6 Psi$ and 1±0.5 respectively. As sisal tend to have the least expansion with highest tensile strength, hence a well-designed sisal rope should be recommended for dry lines.

Keywords: Sisal, Nylon, Rubber, Drying Line.

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1. Introduction

Ropes are essentially useful in our domestic activities. They are ubiquitous, mostly found inside and or outside of our houses. They come in various forms of sizes, thus, big or small and twisted or braided, and different materials such as nylon, rubber, sisal, leather, cotton, etc. However, some of these ropes lose their capacity of supporting a high load after a short period due to weather condition, the heavy load of clothes, etc. They often sag or tear exposing items hung on them, to the ground. We believe that ropes with high elasticity sag faster than those of low elasticity. Hence, there is a real problem of making the clothes dirty by bringing them closer to the ground and rendering the ropes useless after a period.

1.1 Background

Sisal

Sisal is a strong natural fiber obtained from the sisal plant called *Agave sisalana*. It offers almost 80% of its strength due to the high proportion of cellulose. It is durable, inelastic and tough, but has low maintenance to wear or tear. The application of Sisal can be seen in the textile industry: for making cloth. It is also used together with fiberglass to form a composite in the automobile industry. Some carpets used in various homes are all made from sisal. The shipping industry uses sisal ropes to moor small craft. In a research article published by Gupta *et. al.,* the tensile strength of sisal was found to be 132.73MPa [1].

Nylon

Nylon is a synthetic polymer consisting of Hexamethylenediamine. It was first made in DuPont Chemicals laboratory, USA by passing it through solutions to increase its plasticity. Nylon did not have a share market until 1940 when it was first introduced in the production of clothing especially stockings for women's wear. Fortunately, the increase in demand for these ropes has led to a keen competition between synthetic products and biodegradable products. Most of the ropes produced are usually nylon, rubber and sisal. According to Laird Plastic, a renowned plastic company recorded 82.7MPa as the tensile strength of nylon. Nylon has a good elasticity but degrades over time when exposed to sun and this causes it to stretch making it elongated and weak as time goes on. It is also strong and has good resistance to damage from oil and many chemicals [2].

Rubber

Moreover, synthetic rubber is a polymer obtained from a petroleum product and has good elasticity. There is also a natural rubber which is obtained from a thick liquid colloidal suspension called latex obtained from plants. Rubber has existed for a long time, history has it that ancient inhabitants in Mexico and Central America used rubber to make balls used in a game called Mesoamerican ball game. Later, Germany made the first synthetic rubber during the War World I to be used for automobile tires. After this event, other research was conducted by the Massachusetts Institute of Technology to find the different properties rubber has hen combined with chemicals. Today the USA is the leading producer of synthetic rubber. Rubber has very good elasticity properties, it is ductile and has a tensile strength of 15-22MPa [3].

1.2 Objectives

The aims of carrying out this project are:

1. To experimentally measure and determine the best rope for a dry line using statistical analysis.
2. To learn how statistical techniques fit into the general process of solving engineering problems.

1.3 Problem statement and Research findings

In researching the application of ropes as dry lines, Berekuso, a town in the Eastern Region of Ghana, was used as a case study. Over 20 houses were visited, and some observations were made about the types of ropes used in these houses. The data collected revealed that 90% of the ropes being used for dry lines were made of nylon, whereas 4% were made from rubber and 2% from sisal, but not used for dry lines.

Observations

1. 100% of the houses visited use synthetic ropes for dry lines.
2. 40% of these houses have sagged dry lines which expose clothes to the ground.

Selection of ropes for dry line

Based on our observation we proposed the hypothesis that the sagging of the ropes was due to the overwhelming burden and high expansibility, hence there could be a superior substitute for dry lines. This informed the decision to gather an accessible sample of ropes to experiment with them.

Figure 1. A picture of the three samples: nylon(green), rubber(orange) and sisal (white).

2. Methodology

2.1 Design of experiment

The strand of sisal and rubber were twisted to form a rope in the same way as nylon is twisted. This was to eliminate bias in the design matrix. Again, the three ropes were cut into an equal length and their diameters were measured.

Collection of data

Using a Pasco machine, a force was applied to each of the materials. The force applied and displacement (change in length) were recorded. Knowing the original length of each, the strain was calculated by dividing the displacement by the original length. The stress was also calculated by dividing the applied force on each rope by its area of the sample.

Statistical analysis

During the experiment, the data collected was continuous.

One way Anova analysis was carried out in Microsoft Excel and Graphpad. First, the null hypothesis was stated on the assumption that the mean values for the materials' strain are equal. Second, the confidence level of our data by using interval estimates and a 0.05 confident interval were determined. This allowed us to perform a test to determine whether our null hypothesis was true or false from the p-value and confidence level.

2.2 Statistical Test

A normality test: Before we decide to choose Anova or Kruskal-Wallis, we performed the normality test to see whether the data is normal or not. With the help of GraphPad, nonparametric tests such as the D'Agostino & Pearson normality test, Shapiro-Wilk normality test and KS normality test [6] were performed to provide analysis that will not rely on assumptions that the data are drawn from a normal distribution.

D'AGNOSTINE & PEARSON NORMALITY TEST		
K2	18.49	12.18
P value	<0.0001	0.0023
Passed normality test (alpha = 0.05)	No	No
P value summary	****	****
SHAPPIRO WILK NORMALITY TEST		
W	0.9212	0.953
P value	0.0026	0.0454
Passed normality test (alpha = 0.05)?	No	No
P value summary	**	**
KS NORMALITY TEST		
KS Distance	0.09932	0.07109
P value	>0.1000	>0.1000
Passed normality test (alpha = 0.05)?	Yes	Yes
P value summary	ns	ns

Table 1. Results on normality test.

From the table above, the D'Agostino & Pearson normality [5] test gave a p-value (0.0001), which is less than our CI value (0.05), Shapiro-Wilk normality test also gave a p-value (0.0026) which is also less than our CI value. Since the p-values are less than our CI value, it implies the data is not normal. Although the KS normality test gave a p-value (0.09932) which is greater than our CI value, the other two tests that agreed with one another made us ignore the result obtained by KS. This is because KS based its p-value on the largest discrepancy of the distribution which is efficient for accessing two samples, and not the three samples.

Performing the One Way ANOVA (nonparametric);

Using Graph Pad software, the nonparametric test was performed, and the table below depicts the results obtained.

TABLE ANALYZED	ONE-WAY ANOVA DATA
Kruskal-Wallis test	
P-value	<0.0001
Exact or approximate P value?	Approximate
P value summary	****
Do the medians vary signif. (P < 0.05)?	Yes
Number of groups	3
Kruskal-Wallis statistics	115
Data summary	
Number of treatments (columns)	3
Number of values(total)	336

Table 2. One-way Anova test Results.

The results from the table infer that the mean values of the samples are different, hence different expansibility. Besides, we reject our null hypothesis since the p-value in the Anova test (0.0001) is significantly smaller than the CI value. However, one of the highest expansibility remains unknown.

Post Hoc Test

To investigate how far the difference of expansibility is, a Post Hoc Test was performed. This test is a stepwise multiple comparisons procedure used to identify sample means that are significantly different from each other. It is used often as a post hoc test whenever a significant difference between three or more sample means has been revealed by an analysis of variance (ANOVA).

Number of families	1				
Number of companies per family	3				
Alpha	0.05				
Dunn's multiple comparisons tests	Mean rank diff	Significant?	Summary	Adjusted P-value	
Sisal vs Nylon	-132.5	Yes	****	<0.0001	A-B
Sisal vs Rubber	-117.8	Yes	****	<0.0001	A-C
Nylon vs Rubber	14.63	No	ns	0.8403	B-C
Test details	Mean rank 1	Mean rank 2	Mean rank diff.	n1	n2
Sisal vs Nylon	100.1	232.5	-132.5	122	122
Sisal vs Rubber	100.1	217.9	-117.8	122	122
Nylon vs Rubber	232.5	217.9	14.63	122	122

Table 3 Post Hoc Test Results

From the table above, when the mean value of sisal was compared to that of Nylon, the p-value that was obtained is 0.0001. This value is smaller than our CI value which implies that there is a statistical difference between the two mean values. Hence, those two are not related. Moreover, when the sisal mean value was compared to that of Rubber, the p-value was also 0.0001 which is likewise smaller than the CI value. Therefore, proving the statistical difference between the two. However, when nylon was compared with rubber the p-value was 0.8403 which is greater than our CI value. This implies that there is no statistical difference between the two. This test shows that statistically, sisal is different from nylon and rubber.

Material science analysis

It is seen that sisal is statistically different from the others, however, we could not affirm in what sense it is unique to the other samples. With knowledge from material science, we can look at the tensile strength and elastic modulus of the three examples to tell which one has the least expansibility.

3. Results

Sample	Ultimate Tensile Strength(MPsi)	Elastic Modulus (MPa)
Sisal	**84.6**	3084
Nylon	14.07	516
Rubber	53.2	14.5

Table 4. Ultimate tensile strength and elastic modulus of the three samples.

From the above table, Sisal has the highest ultimate tensile strength which is followed by Nylon and after that, rubber. The order is still the same in terms of the elastic modulus. This, therefore, implies that Sisal is better than Nylon in terms of using as a dry line because it has the least expansibility. Again, we recorded data on the stress obtained at the same strain points using Microsoft Excel

Samples	Sample size	Mean	Median	Variance	Standard deviation	Standard error
Sisal	5	51.78	53.7	992.367	31.501857	15.75092
Nylon	5	9.1	10.8	25.31	5.030904	2.515452
Rubber	5	4.14	4.3	0.988	0.993982	0.496991

Table 5. Table showing major statistical variables.

T-Test

We, therefore, had two groups and hence we performed a t-test. Since the data from each sample was independent of each other, we concluded that an unpaired t-test is appropriate. It was assumed that the mean values of their strain would be the same, so this was our null hypothesis.

Discussion

After inferring that sisal has the least expansion and therefore good for making a dry line, it was decided to find out how it can be put together to make a stronger rope. As such two samples of sisal were made. One was designed by twisting two strands of sisal and the other was made by putting two strands together side by side. Using the Pasco machine, the tensile strength was tested. As previously described the stress and strain of each was calculated

Table Analyzed	Unpaired T-test data
Column B vs Column A	Twisted vs Joined
Mann Whitney test P value Exact or approximate P value	 0.8035 Exact
P value summary Significantly different (P < 0.05)? One- or two-tailed P value?	ns No Two-tailed
Sum of ranks in columns A, B Mann Whitney U	2489, 2562 1214
Difference between medians Median of Column A Median of Column B Difference: Actual Difference: Hodges-Lehmann	 0.08167, n=50 0.08363, n=50 0.001959 0.001954

Table 6 T-test Result.

After the t-test, the p-value obtained was 0.8035 which is greater than our confidence level, therefore, implying that there is no statistical difference between the two design. So, either way of designing a rope for a dry line using sisal will still have the same strength, statistically.

4. Conclusion

4.1 Limitation.

Our model revealed sisal to be the toughest material, it failed to predict whether sisal will still hold its "integrity" when subjected to different factors. We hope to collect and analyze data on sisal when exposed weather conditions and mechanical strain. Our computed values as compared to literature values were slightly higher, which we attribute to operational errors while using the Pasco machine during the experiment. The nature and limit of the Pasco machine require little strand of every one of the rope samples, consequently, it did not enable us to perform the test on ropes with a large thickness.

4.2 Conclusion and Future Works

We can conclude that sisal has the least expansion, hence we suggest it to be the best rope for making a dry line. Due to the lack of materials, we could not determine the behavior of sisal when it experiences various conditions, for example, higher temperature and moist conditions. However, it should be noted that, even though we have declared it as the best for making a dry line, we cannot guarantee how durable it may be when exposed to different conditions. As such, we intend to research the performance of sisal in weather conditions in our future works, we will in this manner consider structuring our analysis to discover the quality of sisal when exposed to a few conditions.

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6. References

[1] M. Gupta et al. “Tensile and flexural properties of sisal fiber reinforced epoxy composite: A composite between unidirectional and mat forms of fibers”. P. 2439. 2014 Retrieved from http://www.sciencedirect.com/science/article/pii/S2211812814008542

[2]Laird Plastics. 2016. Retrieved from https://www.lairdplastics.com/product/materials/nylon/3350-nylon-101

[3] R. Kaufman. “Aztec, Maya were rubber-making masters?” 2010 Retrieved from http://news.nationalgeographic.com/news/2010/06/100628-science-ancient-maya-aztec-rubber-balls-beheaded/

[4] T. Renner et. L. Pék. Comparing strength properties of natural and synthetic rubber mixtures. 2011. Retrieved from www.scad.ugent.be/journal/2011/SCAD_2011_2_1_134.pdf

[5] Normality test. *Graph pad*. 2010. Retrieved from https://www.graphpad.com/support/faqid/959/

[6] P. Royston, “Remark AS R94: A Remark on Algorithm AS 181: The W-test for Normality” Journal of the Royal Statistical Society. 1995.