An Analysis of the Breaking Point of Fishing Knots

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1 Introduction

Recreational and commercial fishermen alike are confronted with the task of tying knots. The type of knot they tie is generally a subjective matter based on their own personal experience. Their experience may say that a knot that is consisted of 8-twists is stronger than a knot of 5-twists. While others may attribute their knot's strength to a specific class of knot. A common thread that runs through each of these fishermen's minds, recreational or commercial, is that finding proper knot characteristics is critical to the performance of their knot. The goal of this analysis is to find which factors or combination of factors impact the breaking point of a fishing knot.

2 Data

Factors and Levels

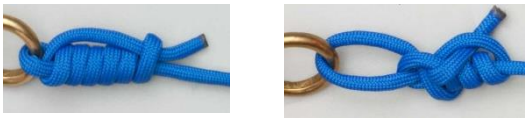
There may be numerous factors which influence the breaking point of a fishing knot. For generality, we only considered three factors at two levels that arise naturally when tying a knot.

A. Type of Fishing Line (Line)

The type of fishing line one uses can vary depending on the situation they face. For the study at hand, we looked at monofilament (-) and fluorocarbon (+) fishing line.

B. Class of Fishing Knot (Class)

The type of fishing knot can be placed into two regimes, namely being slip (-) and non-slip (+). Slip knots are knots that slip down to the eye of a fishing hook and non-slip knots are knots which do not slip down to the eye of a fishing hook.



(a) slip knot (b) non-slip knot

Figure 1: Two classes of fishing knots

C. Knot-Twists (Twists)

The number of knot-twists that make up a fishing knot was considered in this experiment. The two levels looked at were 5-twists (-) and 8-twists (+).

Response

The experiment response was measured with a spring pull gauge which recorded the breaking point of the fishing knot in pounds. The response was recorded in pounds because line manufacturers rate the strength of their line based on its unknotted breaking point in pounds – also known as the test of the fishing line. For this experiment, 10-pound test fishing line was used.

3 Experimental Design

The objective of this study is to find out which factors play a significant role in the breaking point of a fishing knot. It is in our interests to not only focus on main effects but interaction effects since we want to find out optimal knot characteristics which lead to the highest breaking point. Hence, the design used for this

experiment was a 2^3 full-factorial design with 4 replicates as shown in Table 1.

	Line	Class	Twists	I	II	III	IV
(1)	-	-	-	5	7	8	7.25
ab	+	+	-	5	6.25	7	6.25
a	+	-	-	2	5.25	4.25	3
b	-	+	-	7.25	10.25	8.25	10.25
ac	+	-	+	6	5	5	4.25
bc	-	+	+	10.25	10	11.25	11
abc	+	+	+	6	3.25	4	3.25
c	-	-	+	7	7	9.25	10

Table 1: 2^3 full-factorial design with 4 replicates and response data

4 Statistical Analysis

A. Analysis of Variance and Half-Normal Plot

In Table 2, the results from the experiment are displayed in the ANOVA table. The main effects that appear to be significant are type of line (monofilament and fluorocarbon) and class of knot (slip knot and non-slip knot). The significant two-way interactions are between type of line and knot-twists and class of knot and knot-twists. There is also a significant three-way interaction between type of line, class of knot, and knot-twists.

Source	DF	SS	MS	F	P-V
A (Line)	1	117.236	117.236	79.22	0.000
B (Class)	1	21.533	21.533	14.55	0.001
C (Twists)	1	3.283	3.283	2.22	0.149
A (Line)*B (Class)	1	4.314	4.314	2.92	0.101
A (Line)*C (Twists)	1	8.768	8.768	5.92	0.023
B (Class)*C (Twists)	1	7.268	7.268	4.91	0.036
A (Line)*B (Class)*C (Twists)	1	6.346	6.346	4.29	0.049
Error	24	35.516	1.480		
Total	31	204.264			

Table 2: ANOVA Table

The half-normal plot gives us a visual representation of the factor effects in our model. As seen in Figure 2, factors A, B, AC, BC, and ABC all appear to be significant.

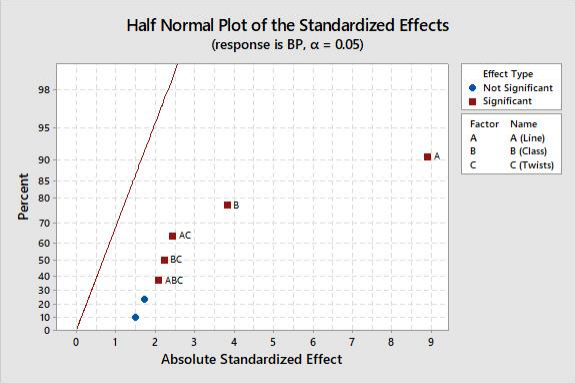


Figure 2: Half Normal Plot

Since there is a significant three-way interaction, a reduced model with only two-way interactions or main effects will not be considered. We will include all factors and interactions into the model for analysis.

B. Model Validation

The normal probability plot given in Figure 3 indicates our model fit is sufficient since there are not any significant deviations shown in the plot. Therefore, the model assumption for normality is satisfied.

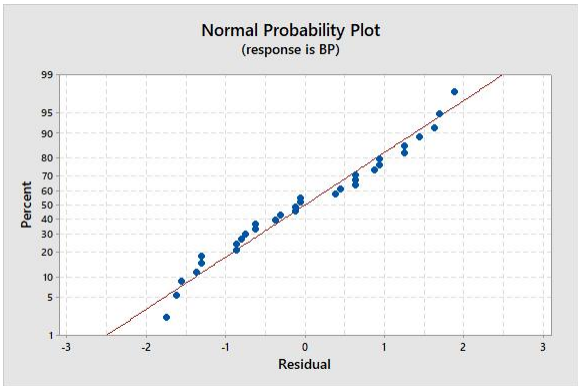


Figure 3: Normal Probability Plot

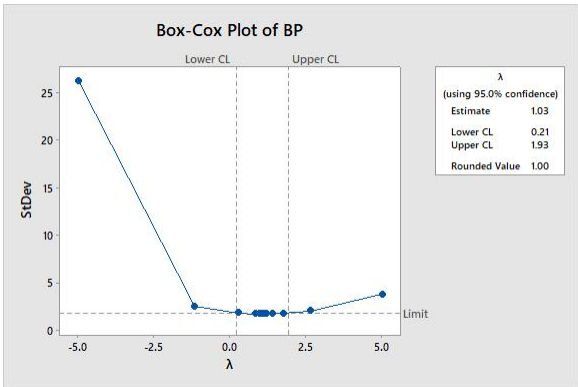


Figure 4: Box-cox Plot

The Box-Cox Plot shown in Figure 4 illustrates that the variation in our model is constant since the minimum occurs around 1 indicating a transformation is not needed.

C. Residual Analysis

Figure 5 shows that the residuals for factor A has constant variance across both levels and we get a similar result show in Figure 6 for factor B.

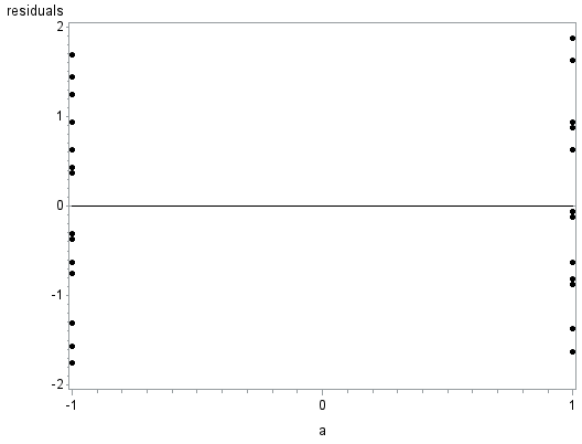


Figure 5: Type of Line (A) residuals

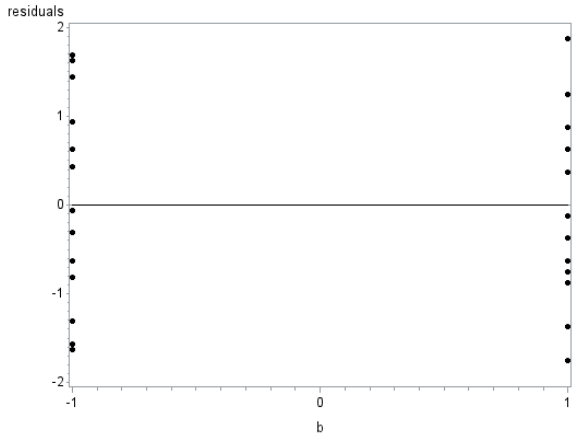


Figure 6: Type of Line (B) residuals

5 Analysis of Main and Interaction Effects

Now that we have an indication of which factors play a significant role in the model, we can use cube, main effect, and interaction plots to construct a way to make interpretations of our findings. For the main effects plot, we can see in Figure 7 the factor which had the highest mean breaking point (8.63 pounds) was type of line at the low-level (monofilament) and lowest mean breaking point (4.8 pounds) at the high-level (fluorocarbon)

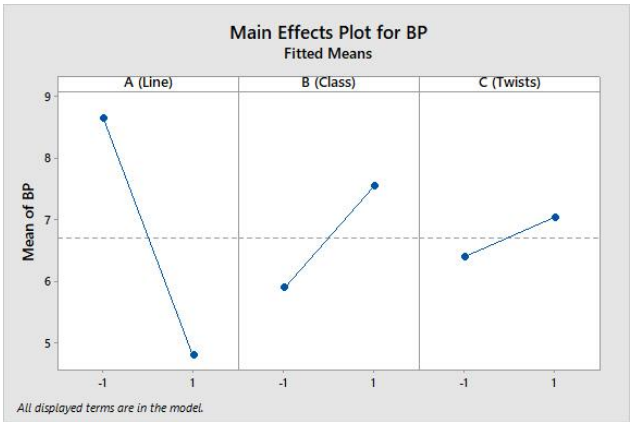


Figure 7: Main Effects Plot

Term	Effect
Constant	
A (Line)	-3.828
B (Class)	1.641
C (Twists)	0.641
A (Line)*B (Class)	-0.734
A (Line)*C (Twists)	-1.047
B (Class)*C (Twists)	-0.953
A (Line)*B (Class)*C (Twists)	-0.891

Table 3: Effect Estimates

Effect estimates shown in Table 3 shows that the effect of factor A should be at the low-level, factor B should be at the high-level, and factor C does not have that significant of an effect.

The two-way interaction plot in Figure 8 gives us an informative indication of the min-max breaking point between type of line, class of knot, and number of twists.

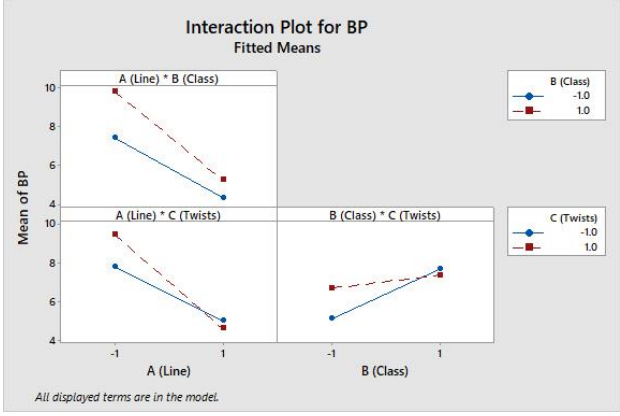


Figure 8: Two-way Interaction Plot

The two-way interaction plot reveals that the highest mean breaking point occurred when monofilament fishing line was used with 8-twists (9.46 pounds). Conversely, the lowest breaking point occurred when fluorocarbon was used with 8-twists (4.59 pounds).

The highest mean breaking point (10.63 pounds) for the three-way interaction occurred when monofilament, non-slip knot, and 8-twists were used to record the response. However, the lowest mean breaking point (3.63 pounds) occurred when fluorocarbon, slip knot, and 5-twists were used as shown in Figure 9.

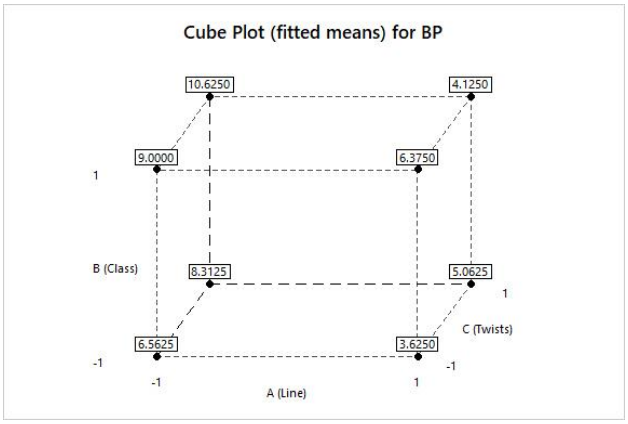


Figure 9: Cube Plot

6 Conclusion

After a thorough analysis of the breaking point of fishing knots, we were able to figure out an objective way to determine which knot characteristics yield the highest breaking point. Main effects and even two-way interactions only determined a partial understanding of the mean breaking point. As it turned out, the three-way interaction resulted in determining the highest mean breaking point (10.63 pounds). For the inquiring fishermen the following knot characteristics are suggested: type of line – monofilament, class of knot – non-slip, and number of twists – 8-twists.