Fishing for the Best Line: Evaluating Polymers used for Sport Fishing

Sarah E. Leach
Mechanical Engineering Technology, Purdue University

Abstract - This paper presents an experiment used in an introductory class in materials for engineering technology. Students review product literature from several types of commercially available fishing line, determine what mechanical properties are of interest, and then make appropriate measurements. The experiment allows students to compare the mechanical properties of different polymer materials, and to compare measured results with advertised specifications.

Procedure - Samples of fishing line are provided to the students, along with product descriptions from the manufacturers, and background and application information. The advertising claims, imaginative product names (IronSilk™, SpiderWire™, Sufix® TriTanium™ Plus) and range of product prices readily lead to questions about material properties the students can explore. The descriptive information is organized into a table and used to create sample groups for tabulation of results. Table 1 shows descriptions for three sample groups, all of which have the same advertised rating of six pounds “test”. The first two sample groups are nylon, and the third group is a fluoropolymer alloy, described by the manufacturer as a fluorocarbon. The materials are available in spools of 100 yards in length or more.

Table 1 – Sample Group Descriptions

Sample Group	Manufacturer	Type	Material	Lbs. Test	Cost ($/yard)
1	Eagle Claw	Ambassador Eagle, Premium	Nylon monofilament	6	0.0022
2	Stren[1]	Original, clear blue	Nylon monofilament	6	0.0339
3	Yo-Zuri[2]	Hybrid, camo green	Fluorocarbon polymer alloy	6	0.0290

Six samples of each type of line are cut, with each piece approximately 12 inches in length. The diameter of each type of line is recorded, and the students calculate the cross-sectional area for each group.

Using a permanent marker and a scale, 2 inch gage lengths are marked on each sample. For identification it is helpful to use a different color marker for each sample group. Drafting tape or PostIt™ notes can be used to hold the lines straight for marking. A smooth washer, small wire rings or other hardware should be tied to at least one end each end of each sample, and preferably to both. This hardware is helpful in preventing damage to the samples during testing. The polymer samples are very sensitive to nicks, kinks, scratches or other damage. The measured properties of the polymers are also sensitive to the style of knot used to affix the hardware. Data are shown in this paper for samples tested with hardware on one end, using simple overhand knots, and for samples prepared with hardware on both ends, tied with "Palomar" knots. Care must be taken to knot the line to form a loop, without damaging the line or leaving the knot so loose that the line slips through the knot when tension is applied. Three samples from each group are submerged in room temperature tap water for analysis after a one hour soak.

Using a spring gage, data are collected for the elongation at rated strength and ultimate tensile strength for each sample. For measurements on samples with hardware on one end only, the sample should be held parallel to a table or other flat surface, on which a scale has been place above a light-colored background. Students should work in teams of two or more, to apply tension to the sample and monitor the elongation between the gage marks. The loop on one end of the sample should be attached to the hook on the spring gage. The free end of the sample should be grasped with a pair of pliers or other mechanical gripper. Students should **not** attempt to perform the test by pulling on the line with their bare fingers.

When samples have been prepared with hardware on both ends, a vise or clamp can be used to hold one end of the sample, and a spring gage used to apply force. This technique is illustrated in Photo 1. Table 2 lists the raw data for the three sample groups , for dry and soaked samples, prepared with overhand knots. Using the formula for direct tensile stress, $\sigma = F/A$, students calculate the tensile strength for each sample group and test condition. Average values for Ultimate Tensile Strength are presented in Table 3, along with the material type for each group. It is important to note that many of the samples failed at loads near or below their strength. The experiment was repeated using a Palomar knot recommended by one of the manufacturers[3]. Table 4 lists data collected from samples prepared with Palomar knots, with hardware (polymer washers) at both ends. A summary of the measured and calculated values for the second trial is shown in Table 5.

Photo 1 - Testing with spring gage, washers on both ends of sample.

Comments - The choice of knotting technique had a significant impact on the measured strength of all three materials. The data for these tests using the overhand knot indicate that the lowest cost material, the .012 inch diameter nylon monofilament appeared to have the highest load strength, but that may be a consequence of the larger diameter creating less knot sensitivity, not the inherent tensile strength of the material. The 0.010 diameter nylon had a higher tensile strength dry, but after a one-hour soak in tap water, the material failed at the knot used to create the loop for the spring gage. The fluorocarbon material was least affected by the soak, loosing only approximately 28,000 psi of tensile strength. It was not possible with any of the materials to make significant measurements of the elongation at their rated load using the overhand knot, since they had an average breaking strength below the rated load. It is not clear why this was the case for the dry samples, because the failures were not associated with the knots or grips used to apply the load. The number of failures at the knot locations for the soaked samples indicate that the combination of knotting and soaking caused a significant increase in local stress, leading to failure.

Table 2 – Raw Data from Tensile Tests, Overhand Knot, Single-end Hardware

Sample Group (three samples for each group for each test condition)	Condition	Length at Rated Load of 6 Pounds (inches)	Ultimate Tensile Load (pounds)	Break Note
1	Dry	2.38	6	
1	Dry	broke < rated load	4	
1	Dry	2.5	6.5	
1	Soaked	2.5	6	
1	Soaked	broke < rated load	4.5	
1	Soaked	broke < rated load	4.5	
2	Dry	broke < rated load	4.25	
2	Dry	broke < rated load	4.5	
2	Dry	broke < rated load	5.25	
2	Soaked	broke < rated load	2	near knot
2	Soaked	broke < rated load	3	near knot
2	Soaked	broke < rated load	2.5	near knot
3	Dry	broke < rated load	4.25	
3	Dry	broke < rated load	4	
3	Dry	2.38	6.25	
3	Soaked	broke < rated load	4	near knot
3	Soaked	broke < rated load	2.5	near grips
3	Soaked	broke < rated load	5	

Table 3 – Summary of Results, Overhand Knot, Single-end Hardware

Sample Group Average	Material Type	Diameter (inches)	Average Breaking Load, Dry (pounds)	Ultimate Tensile Strength, Dry (psi)	Average Breaking Load, Soaked (pounds)	Ultimate Tensile Strength, Soaked (psi)
1	Nylon	0.012	5.5	109,000	5	99,000
2	Nylon	0.010	4.7	134,000	2.5	72,000
3	Fluorocarbon	0.010	4.8	138,000	3.8	110,000

Table 4 – Raw Data from Tensile Tests, Palomar Knot, Double-end Hardware

Sample Group (no soaked samples for test group 2)	Condition	Length at Load of 5 Pounds (inches)	Ultimate Tensile Load (pounds)
1	Dry	2.38	6.5
1	Dry	2.38	6.25
1	Dry	2.38	6.25
1	Soaked		5.25
1	Soaked		6.25
1	Soaked		6.0
2	Dry	2.31	6.0
2	Dry	broke < 5 pounds	3.75
2	Dry	2.44	6.0
3	Dry	2.38	5.75
3	Dry	2.31	8.5
3	Dry	2.31	7.5
3	Soaked		5.25
3	Soaked		5.5
3	Soaked		6.25

Table 4 – Summary of Results, Palomar Knot, Double-end Hardware

Sample Group Average	Material Type	Diameter (inches)	Elongation (%)	Average Breaking Load, Dry (pounds)	Ultimate Tensile Strength, Dry (psi)	Average Breaking Load, Soaked (pounds)	Ultimate Tensile Strength, Soaked (psi)
1	Nylon	0.012	19	6.3	126,000	5.8	116,000
2	Nylon	0.010	19	5.3	150,400		
3	Fluorocarbon	0.010	17	7.3	207,700	5.7	162,000

When samples were tested with the Palomar knot, the fluorocarbon material had the highest measured tensile strength, but was more significantly affected by the soak than the nylon monofilament. This is an important observation in this experiment, since use of a line for sport fishing typically requires both knotting and soaking. The Eagle Claw brand monofilament had a higher measured breaking strength dry than the Stren monofilament, but this was apparently a consequence of the larger diameter of the Eagle Claw material, not its inherent tensile strength. Students enjoyed comparing their measurements with manufacturer's specifications and comparing the relative costs of the materials tested.

Significant work has been done in the area of testing fishing line. References 4 and 5 below by Wayne L. Elban are very good sources for information about fracture behavior and structuring a lab experience around knot selection. The other references below are general resources for fishing line material or information.

References

1. Stren, P.O. Box 700, Dept. BSN, Madison, NC 27025; 1-800-243-9700; www.stren.com

2. Yo-Zuri, 513 N.W. Enterprise Dr., Dept. BSN, Port St. Lucie, FL 34986; 1-888-336-9775; **www.yo-zuri.com**

3. "Choosing and Using Lines and Knots: with Lefty Kreh" Form No. L00128, 1995, Stren Fishing Lines, Remington Arms Company, Inc., 870 Remington Drive, Madison, North Carolina, 27025

4. Elban, W.L.: Fracture Behavior of Nylon Monofilament Fishing Line, in National Educators' Workshop: Update 2000, NASA/CP-2001-211029, 2001, pp. 81-112.

5. Elban, W.L., and Frantz, D.L.: Fishing Line Knot Tying Contest: A Freshmen Experience, in National Educators' Workshop: Update 2001, NASA/CP-2002-211735, 2002, pp. 149-170.

"Choose the Right Fishing Line", Bassin', pp. 38-41 on www.ebassin.com

Berkley, 1900 18th St., Dept. BSN, Sprit Lake, IA 51360; 1-877-777-3850; www.purefishing.com

Cajun Line, 3801 Westmore Dr., Dept. BSN, Columbia, SC 29223; 1-800-347-3759; www.cajunline.com

Seaguar, 513 N.W. Enterprise Dr., Dept. BSN, Port St. Lucie, FL 34986; 1-888-336-9775; www.seaguar.com

Silver Thread, 3601 Jenny Lind Road, Dept. BSN, Fort Smith, AR 72901; 1-800-531-1201; www.lurenet.com

Triple Fish, 1240 Commons Ct., Dept. BSN, Clermont, FL 34711; (352) 243-0873; www.TripleFish.net

Kenneth G. and Michael K. Budinski, Engineering Materials: Properties and Selection, Seventh Edition, Prentice Hall, Upper Saddle River, New Jersey, 2002

Robert L. Mott, Applied Strength of Materials, Fourth Edition, Prentice Hall, Upper Saddle River, New Jersey, 2002

Biography

SARAH LEACH is an assistant professor of MET at Purdue University Elkhart/South Bend. Her primary teaching responsibilities are in materials and applied mechanics. She remains an active member of ASME and ASEE, and serves as the faculty advisor for the local student chapter of the American Society of Mechanical Engineers.