Analysis and Characterization of Household Duct Tape Brands

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Abstract. This investigation aims to characterize the material properties of various common household duct tape brands. Tape samples from each of the four brands (Duck, 3M, Scotch, and Gorilla) were tested to failure using an Instron following the specifications of ASTM D882. The results were used to calculate/measure the Young's modulus, yield strength, and ultimate strength of each material. Testing revealed significant variation between brands, with Duck brand tape exhibiting the highest Young's modulus at 452 MPa, while Scotch brand tape had the lowest at 196 MPa. For yield strength, Scotch tape had the highest at 12.4 MPa while 3M tape had the lowest at 2.7 MPa. Finally, for ultimate strength, Duck tape had the highest at 18.9 MPa while Gorilla tape had the lowest at 12.4 MPa. Based on a cost analysis of the data, Duck brand tape provides the best overall value for money.

1. INTRODUCTION

Duct tape is a common household and industrial tool, valued for its strength and cost. However, there are rarely any metrics for the strength of these tools beyond product descriptions. Understanding properties such as stiffness, yield strength, and tensile strength can be critical for applications ranging from minor repairs to demanding engineering projects. While it is an industry standard practice to conduct thin film tests on plastics such as for battery construction, no major papers have addressed a comparison despite duct tapes' widespread use. In this project, we investigated this gap by characterizing the mechanical properties of four widely available duct tape brands—Duck, 3M, Scotch, and Gorilla—using ASTM D882 testing protocols. Additionally, we did a cost-performance analysis to select the most effective and economical tape for specific needs. By filling this gap in knowledge, the research aims to guide informed decision-making for both consumers and industry professionals.

2. EXPERIMENTAL DESIGN

The basis for testing thin film materials such as tapes and plastics is defined by ASTM D882: Standard Test Method for Tensile Properties of Thin Plastic Sheeting. Commonly used for thin film materials, especially with the popularity of thin film technology in lithium ion batteries, this spec was most similar to our situation and our intended testing goals.

2.1. Definitions

Symbol	Definition	Units
w	Tape Width	mm
t	Tape Thickness	mm
l	Tape Length	mm
F	Load	N
ϵ_f	Extension	mm
E	Young's Modulus	MPa
σ_y	Yield Strength	MPa
σ_u	Ultimate Strength	MPa
η	Cost Efficiency	\$/m

Table 1: Variables

Variable	Uncertainty
F	0.000005
w	0.00127
t	0.0005
ϵ_f	0.000005
l	0.0025

Table 2: Precision Uncertainties

Precision uncertainties in Table 2 are derived from halving the final digit of precision on the respective measurement tool (Instron for F & ϵ_f, caliper for w, ruler for l, micrometer for t).

2.2. Tape Thickness

This ASTM only applies to thin film plastics ≤ 1 mm. In order to determine the thickness of the tape we took 5 measurements of each tape with a micrometer. From this data, we determined the average thickness, standard deviation, t-value, and uncertainty. Using a 95% confidence interval and 5 samples, we got a a t value of 2.776. In order to account for the precision uncertainty of the thicknesses, we RSS'ed the uncertainties together.

$$U_{combined} = \sqrt{U^2_{statistical} + U^2_{precision}}$$

Our margin of error was then calculated by doing:

$$u_t = t * U_{combined}$$

All measurement data can be found in Appendix A, Table A.1. The average thicknesses, t, and total uncertainties, u_t for our tapes is listed in Table 3.

Brand	$\bar{t}$ (mm)	u_t (mm)
Duck	0.1971	0.0039
3M	0.2113	0.0086
Scotch	0.2052	0.0083
Gorilla	0.4216	0.0042

Table 3: Average Tape t and u_t

Therefore, all of our tapes are compliant with the use of this spec.

2.3. Fixturing

The spec suggests multiple options for constraining the tape, including line grips, rubber grips, serrated grips, etc. According to 5.1.3.3, line grips are especially advantageous and preferred for use with this testing standard. Line grips consist of one flat face and an opposing face which is half-round, allowing the film to be gripped along a single line. This serves as the perfect solution to grip the film without introducing defects, clamping with uneven pressure, or prematurely tearing the material. A side view of line grips is shown in Figure 1.

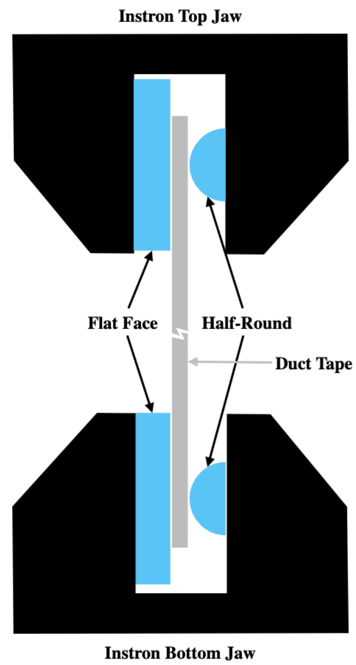

Figure 1: Line Grip Configuration

2.4. Test Specimens and Speed

In order to determine the length of the test specimen, the specification requires a 250mm strip of each material to be tested to failure at a speed of 25 mm/min. After measuring the percent elongation at break, we can determine what length of specimen is needed for all further data collection according to the specification. In our case, all specimens had a percent elongation at break less than 20%, leading to the use of 125mm strips with a grip separation rate of 12.5 mm/min.

Given the large Instron load cell and the relatively small force being applied by the samples, the nominal width of the specimens was chosen to be the max allowed by the specification. Each strip would therefore have a width of 25mm and a length of 125mm to maximize loading for cleaner data collection.

2.5. Number of Specimens and Procedure

Given the anisotropic nature of duct tape, the spec recommends a test procedure with at least six samples in each direction. However, given the short width of tape (about 47mm) when bought in rolls, these perpendicular samples would be too small and non-compliant with our testing spec. Therefore we defaulted to the six sample requirement for isotropic materials. For our testing, we ran one 250mm sample for each tape brand to determine elongation at break, and then six samples to determine all other parameters.

Figure 2: Test Setup

2.6. Data Collection

To collect data, each tape specimen was tested in a controlled environment using the Instron machine in Hesse, ensuring consistent grip separation and load application. Measurements of load (force) and extension (displacement) were recorded during each trial. For each brand, six specimens were tested, providing a robust dataset for statistical analysis. All tests adhered to ASTM D882 specifications, including controlled strain rates and accurate alignment of specimens.

2.7. Data Processing

The raw data from the Instron tests were processed to derive stress and strain values. Stress (σ) was calculated using the formula:

$$\sigma = \frac{F}{w \cdot t}$$

where F is the applied force, w is the tape width, and t is the tape thickness. Strain (ϵ) was determined as:

$$\epsilon = \frac{\epsilon_f}{l}$$

where ϵ_f is the extension and l is the original length of the specimen. The resulting stress-strain data were plotted, and key mechanical properties were extracted.

3. RESULTS

3.1. Elongation at Break

For each of the tapes, we first measured their elongation at break to determine the grip separation rate that would be used for all other tests. For this trial, we only ran one trial per tape brand. The tapes failed at the following elongation values:

Brand	ϵ_f (mm)	ϵ_f (%)
Duck	39.21	15.68
3M	17.95	7.18
Scotch	24	9.6
Gorilla	18.54	7.42

Table 4: Elongation at Break

All of these samples failed at less than 20% elongation, which informed our decision to transition to 125mm samples at a 12.5 mm/min grip separation rate.

3.2. Modulus of Elasticity

In order to determine the modulus of elasticity (Young's modulus, E), we cropped the averaged data to only include the linear region. From there, we took a linear fit of the stress vs strain data. This gave us a Young's Modulus value, E, and the fit associated with the uncertainty, u_{fit}.
The uncertainties of these measurements are calculated using the uncertainty of the factors that influence Young's Modulus and the uncertainty (u_{fit}) associated with the slope of the linear regression calculation.

$$E = \frac{\sigma}{\epsilon} = \frac{\frac{F}{w*t}}{\frac{\epsilon_f}{l}} = \frac{Fl}{wt\epsilon_f} \tag{1}$$

$$\begin{aligned} u_E = \sqrt{\left(\frac{\partial F}{\partial E}u_F\right)^2 + \left(\frac{\partial w}{\partial E}u_w\right)^2 \\ + \left(\frac{\partial t}{\partial E}u_t\right)^2 \\ + \left(\frac{\partial \epsilon_f}{\partial E}u_{\epsilon_f}\right)^2 \\ + \left(\frac{\partial l}{\partial E}u_l\right)^2 \\ + u_{fit}^2} \end{aligned} \tag{2}$$

In order to calculate the total uncertainty, the uncertainties of every variable was determined.

$$\begin{aligned} u_E = \sqrt{\left(\frac{E}{F}u_F\right)^2 + \left(-\frac{E}{w}u_w\right)^2 \\ + \left(-\frac{E}{t}u_t\right)^2 \\ + \left(-\frac{E}{\epsilon_f}u_{\epsilon_f}\right)^2 \\ + \left(\frac{E}{l}u_l\right)^2 \\ + u_{fit}^2} \end{aligned} \tag{3}$$

Calculating the uncertainty of our Young's Modulus gives Table 5 and 6. An example calculation of Duck Tape's uncertainty is shown in Appendix A, Table A.2.

Brand	$\overline{E}$ (MPa)	u_E (MPa)
Duck	452	26
3M	339	23
Scotch	196	13
Gorilla	251	14

Table 5: Young's Moduli w/ Uncertainties

Brand	Min (MPa)	Max (MPa)
Duck	426	478
3M	316	362
Scotch	183	209
Gorilla	237	265

Table 6: Young's Moduli Interval

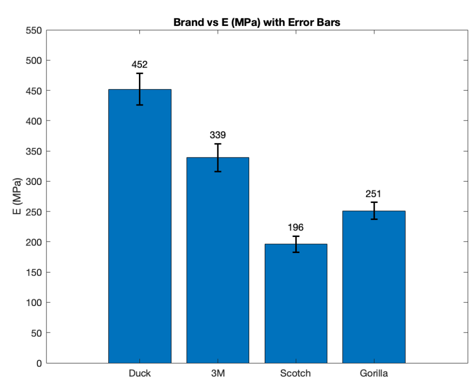

Figure 3: Young's Moduli with Error Bars

3.3. Yield Strength

Yield strength for each tape was determined by finding the point that intersects the linear fit with a 0.2% offset from the stress-strain curve.

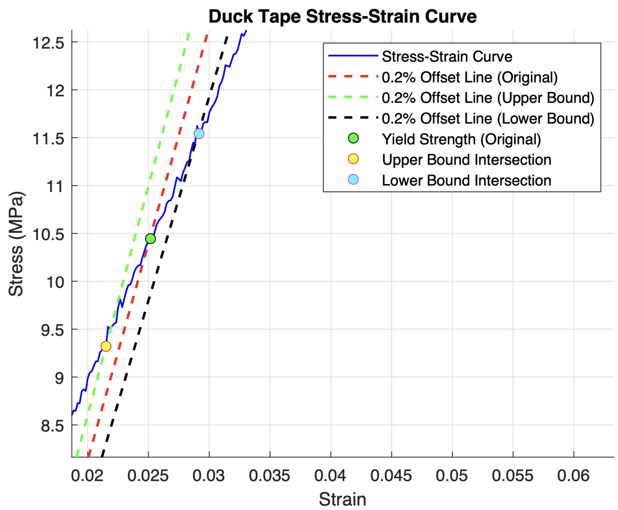

Figure 4: Yield Strength Uncertainty Bounds

The uncertainty for the yield strength was calculated based on the variation in Young's modulus. Two lines were plotted based on the maximum and minimum Young's modulus, and the two intercepts were used to find a maximum and minimum yield strength value. This process can be seen for one brand of tape in Figure 4.

Brand	$\overline{\sigma_y}$ (MPa)	σ_y Max	σ_y Min
Duck	10.45	11.54	9.32
3M	2.74	3.57	2.09
Scotch	12.40	12.66	11.26
Gorilla	5.09	6.57	5.54

Table 7: Yield Strengths of Tapes

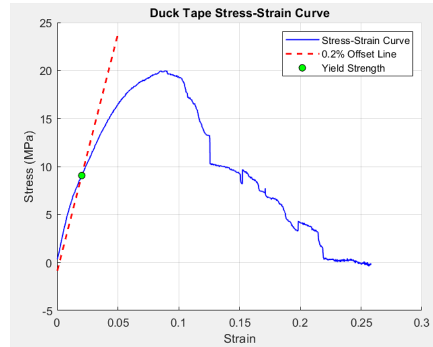

Figure 5: Duck Tape Stress Strain

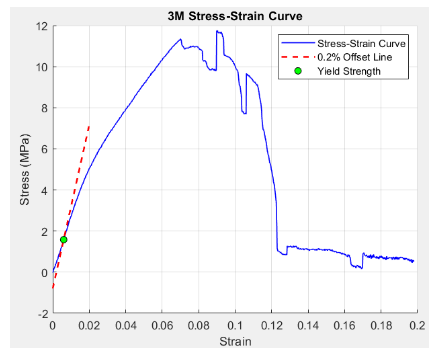

Figure 6: 3M Tape Stress Strain

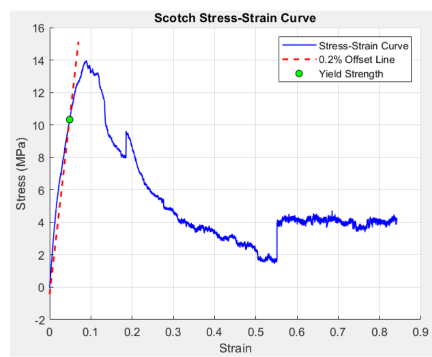

Figure 7: Scotch Tape Stress Strain

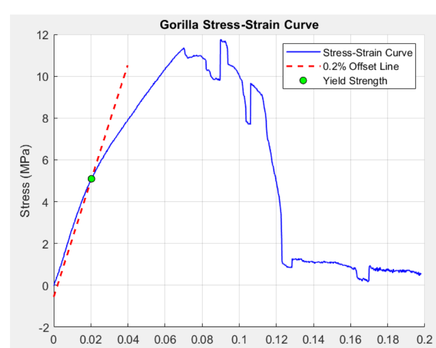

Figure 8: Gorilla Tape Stress Strain

3.4. Ultimate Strength

The ultimate strength of each tape was determined by taking the maximum stress for every trial for each tape and averaging the data. We did a t-test on this data with a 95% confidence interval (t-value of 2.571). This gave us Tables 8 and 9 below.

Brand	σ_u (MPa)	u_{σ_u} (MPA)
Duck	18.9655	1.8294
3M	14.5661	2.1454
Scotch	12.7160	0.8956
Gorilla	12.3849	1.8722

Table 8: UTS of Tapes

Brand	Min (MPa)	Max (MPa)
Duck	17.1361	20.7949
3M	12.4207	16.7114
Scotch	11.8204	13.6116
Gorilla	10.5127	14.2572

Table 9: UTS of Tapes

3.5. Cost Analysis

To conduct a cost analysis, we first determined a cost metric based on \$USD / m. Using non-sale prices (MSRP), we calculated η for all tapes, where $\eta = \frac{\text{Cost}}{\text{Roll Length}}$. This results in the η values in Table 10.

Brand	η (\$/m)
Duck	\$0.18
3M	\$0.38
Scotch	\$0.35
Gorilla	\$0.44

Table 10: Price per meter of tapes

From there, we divided each metric (E, σ_y, σ_u) by η to determine an MPa/\$ metric for each. By normalizing this data, setting the maximum value to 1 and calculating the ratio of the other values, we can create Figures 9 and 10 below.

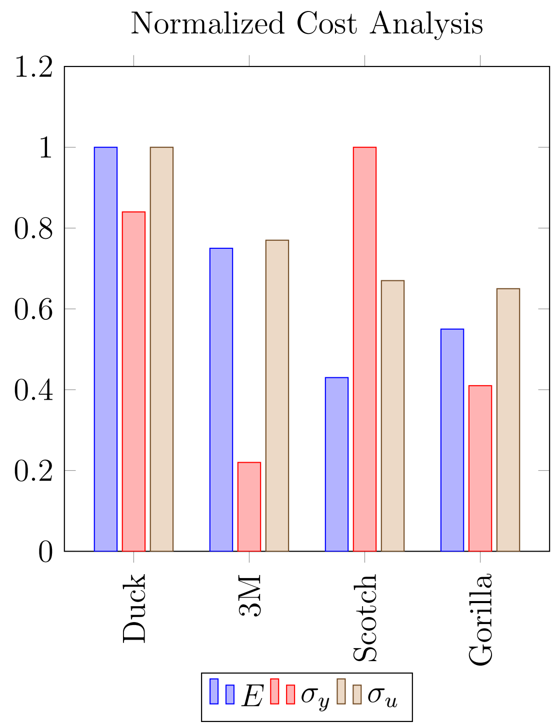

Figure 9: Normalized Properties by Brand

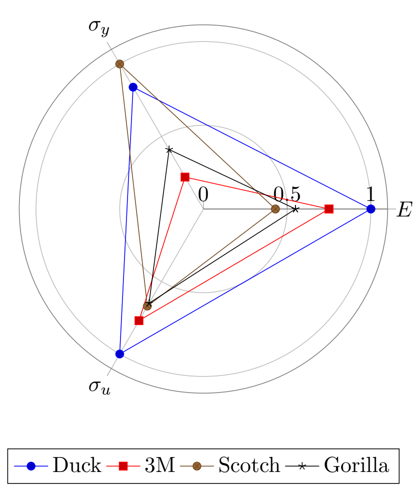

Figure 10: Normalized Properties by Brand

4. DISCUSSION

4.1. Results

The results from our tests reveal distinct variation in the mechanical properties of the four tape brands. Duck tape demonstrated the highest Young's modulus, making it the stiffest tape of the four, while 3M exhibited the the lowest. Scotch tape had the greatest yield strength, indicating its superior resistance to permanent deformation under stress. Duck tape also excelled in ultimate tensile strength, achieving the highest value and demonstrating its ability to withstand the greatest stress before failure. Importantly, 3M tape showed relatively low performance across all tests, with no standout mechanical property. Gorilla tape stayed middle of the pack for most tests; despite it's high load capability, Gorilla tape is twice as thick as the other tapes.

4.2. Cost and Value Comparison

To evaluate cost-effectiveness, we normalized each mechanical property (stiffness, yield strength, and tensile strength) by the cost per meter of each tape. Duck tape provided the best value for all three parameters, making it a cost-efficient choice for all applications. Despite its high thickness, Gorilla tape was less cost-effective due to its premium price of \$0.44/m, which was not sufficiently justified by its mechanical properties.

4.3. Connection to Previous Studies

These findings are consistent with prior research on adhesive tapes, particularly studies focusing on stress-strain behavior in polymer-based materials. Similar trends in mechanical property variations, such as differences in stiffness and strength, have been reported in ASTM-standardized investigations. The observed performance differences can likely be attributed to variations in adhesive composition and substrate materials.

4.4. Study Limitations

The first major limitation of the study was our inability to test anisotropic properties of the tape. Our samples were only tested in one direction and the method ignores the fact that tape may be used perpendicular to this measured direction. This aspect was limited by availability of long enough samples in other directions.

The sample size for each tape brand was also limited due to resource constraints, which may have affected the reliability of the results and our ability to find outliers.

Our method also included sticking the tape to the flat side constraint and having the line grip on the other side. This was done for the purposes of accurate placement and ease of alignment in the Instron jaws. However, this means that the section stuck to the plate was unable to stretch and the adhesive was impacting the data being collected.

5. CONCLUSION

This research provides a comprehensive mechanical characterization of four household duct tape brands. The goal of the research was to characterize the material properties of the tapes, specifically Young's modulus, yield strength, and ultimate strength.

For Young's modulus data, we found that the Duck brand tape to be the highest at 452 MPa, while the lowest was Scotch at 196 MPa. The relatively large range of values does not say anything about the strengths of the tapes, but does showcase the range of stiffness values among different tapes. In situations where users are putting their tapes in tension and do not want large deformation, the high stiffness of Duck tape would be an important consideration.

For yield strength data, we found Scotch brand tape to have the highest yield strength at 12.4 MPa, while 3M had the lowest at 2.7 MPa. However, the value for 3M tape appears to be much lower than the rest as the Duck brand tape has a yield strength of 10.5 MPa and Gorilla tape has one at 5.1 MPa.

Finally, for ultimate tensile strength we found Duck brand tape to be higher than the rest at 19.0 MPa, while the lowest was Gorilla brand tape at 12.4 MPa. The ultimate strength metric is one of the most important in evaluating tapes as this would be the stress above which the tape no longer holds any tension.

Overall the Duck tape excelled in stiffness and ultimate tensile strength while Scotch tape excelled in yield strength. The results underscore the importance of matching tape selection to specific application needs. Broader implications of these results suggest that understanding mechanical properties can optimize tape selection in household and engineering applications. Future research could expand the scope of testing by evaluating adhesive properties, fatigue resistance, and environmental durability under various conditions. Hence, further studies could expand the sample size and include dynamic testing for adhesive performance.

6. ACKNOWLEDGMENTS

We thank the Hesse Lab for providing access to testing equipment, supplies, and advice during our testing. Special thanks to Daniel for guidance on ASTM testing standards and for manufacturing parts of our test fixture.

7. REFERENCES

"Standard Test Method for Tensile Properties of Thin Plastic Sheeting," ASTMD882-18, ASTM International, 2018

Appendix A. APPENDIX

Trial	**Duck**	**3M**	**Scotch**	**Gorilla**
1	0.1981	0.2159	0.2032	0.4216
2	0.1956	0.2007	0.2007	0.4216
3	0.1956	0.2134	0.2032	0.4242
4	0.1981	0.2108	0.2032	0.4216
5	0.1981	0.2159	0.2159	0.4191
Average	0.1971	0.2113	0.2052	0.4216
STDEV	0.0014	0.0063	0.0061	0.0018
SEM	0.0006	0.0028	0.0027	0.0008
$\mathbf{U_{combined}}$	0.0014	0.0031	0.0030	0.0015
$\mathbf{u_t}$	0.0039	0.0086	0.0083	0.0042

Table A1: Tape Thickness Data

Table A2: Tape Thickness Data

E	F	w	t	δ	l
4.52E+08	3.46E+01	2.54E-02	1.97E-04	1.92E-03	1.25E-01
	u_F	u_w	u_t	u_{ϵ_f}	u_l
	5.00E-06	1.27E-03	3.90E-06	5.00E-06	2.50E-03
	$\left(\frac{E}{F} \cdot u_F\right)^2$	$\left(\frac{E}{w} \cdot u_w\right)^2$	$\left(\frac{E}{t} \cdot u_t\right)^2$	$\left(\frac{E}{u_{\epsilon_f}} \cdot u_{\epsilon_f}\right)^2$	$\left(\frac{E}{l} \cdot u_l\right)^2$
	4.27E+03	5.11E+14	8.00E+13	1.39E+12	8.17E+13
u_E		Min E		Max E	
2.60E+07		4.26E+08		4.78E+08	

Table A3: Duck Tape Young's Modulus Uncertainty Calculator