Streamer Duration Optimization: Material and Length-to-Width Ratio

Research and Development
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Abstract

The effectiveness of various materials and length-to-width ratios was tested for streamer duration competition. Sixteen streamers, 4 inches wide and 40 inches long, were prepared from crepe paper, cellophane wrapping paper, yellow tracing paper, 16-lb. white bond paper, Micafilm, 1 mil electrostatic discharge Mylar® packaging film, 1.5 mil Mylar, and DragStrip™ Mylar. Eight additional streamers were prepared from 1.5 mil Mylar, 4 inches wide and 20, 30, 50, and 60 inches long. Each streamer, with the exception of those made from crepe paper, was folded in a straight pattern with ¾-inch pleats over all but the last 4 inches closest to the attachment point. A 5 g weight was attached to each streamer at one corner.

The streamers were dropped a distance of 20.1 m in outdoor tests, and the descent times were recorded. Variable wind conditions created moderate turbulence, which resulted in many of the results being rejected. Analysis of the remaining results showed Micafilm to have the slowest descent rate at 2.04 $m \cdot s^{-1}$. Yellow tracing paper, cellophane, and DragStrip Mylar were close behind at about 2.2 $m \cdot s^{-1}$. Crepe paper had the worst performance at 2.80 $m \cdot s^{-1}$. From the length-to-width ratio tests, it is clear that ratios > 10 yield slower descent rates for 1.5 mil Mylar. An important consideration for streamer duration competition is to build the model to optimum mass. If the model is significantly over optimum mass, it may be advantageous to use a shorter streamer or a lighter weight material such as tracing paper.

Introduction

Streamer duration optimization has been the subject of several studies in the past. The earliest (Barber and Milkie, 1972) studied the effects of material, width and length by performing controlled drops down an air shaft. The materials tested were 0.4 mil polyethylene, 0.25 mil Mylar®, and crepe paper, which was found to be significantly better than the others. At that time, folding techniques had not been introduced, so the better performance of crepe paper was likely due to its textured surface. Performance increased with streamer width for all materials. For crepe paper, performance was nearly constant with streamer length, but performance was generally better for polyethylene and Mylar as length increased. The conclusion from this report was to use crepe paper in a 10:1 length-to-width ratio and to use the largest streamer that can be inserted into a minimum-diameter body tube. This 10:1 ratio was shown to be optimum only for crepe paper, but it has nonetheless remained even as better materials became available.

Flanigan (1976) expanded on the previous work by testing crepe paper and tissue paper in similar indoor drop tests. Performance was nearly the same for crepe and tissue paper, although the thinner tissue paper could be rolled into a smaller diameter tube. Squid line attachment at the center versus at a corner was also tested, with corner attachment yielding much better results.

Sykos (1980) tested streamer materials including white and yellow tracing paper of various weights, and Mylar film of unspecified thickness. The tests were conducted through actual launches, which introduce many uncontrollable variables such as weather and motor performance, instead of drop tests used previously. In addition, the tests were conducted over a long period of time, using different models, folding techniques and streamer sizes. Despite these problems, white tracing paper was determined to be the best material, although other factors may well have influenced the results.

The last significant work on streamer design was by Kaplow and Jones (1984) in which various folding techniques were studied. As in earlier studies, indoor drop tests were used to eliminate the effects of weather. Good statistical analysis in this report clearly showed that straight folds over the entire length of the streamer produced the best results.

The goal of this report is to provide a conclusive test of various materials, including different types of Mylar not previously available. The effect of changing the length-to-width ratio of folded Mylar will also be investigated. The performance of the streamers will be measured through drop tests, and statistical analysis will be used to study the results.

Experimental

Sixteen streamers, 4 inches wide and 40 inches long, were prepared from the following materials: crepe paper, cellophane wrapping paper, yellow tracing paper, white 16-lb bond paper, Micafilm, 1.0 mil electrostatic discharge (ESD) Mylar packaging film, 1.5 mil Mylar, and DragStrip™ Mylar. Sources for these materials are listed in the appendix. Eight additional streamers were cut from 1.5 mil Mylar, 4 inches wide and 20, 30, 50, and 60 inches long. Two streamers for each material and length were created, with results averaged for the pairs. Each streamer was weighed to 0.0001 g using a Mettler AX105 analytical balance, with results summarized in Table 1. A weight was attached to each streamer at one corner using a 6-inch length of Kevlar thread. Masses for the attached weights and the total assemblies are also include in Table 1. Each streamer, with the exception of those made from crepe paper, was folded in a straight pattern with ¾-inch pleats over all but the last 4 inches closest to the attachment point.

The original intent was to perform the drop tests indoors to eliminate meteorological effects, but no suitable locations were available. Instead, the tests were conducted from Byrd Stadium at the University of Maryland at College Park, with the streamers dropped from the middle deck of the stadium to the ground, a distance of 20.1 m. An assistant on the ground timed each drop using a stopwatch readable to 0.01 s. The streamers were released fully unfurled, and radio communication was used to notify the assistant when to start timing. The tests were performed on the morning of March 3, 2001, with variable winds generally less than 3 $m \cdot s^{-1}$. The stadium shielded the prevailing wind from the west, but created turbulence which affected many of the tests. Each streamer was dropped approximately 9 times before the wind increased to greater than 5 $m \cdot s^{-1}$ and the tests were halted. Some streamers were dropped fewer times because they were torn or the weights detached from the squid line.

Results and Discussion

Raw data from the drop tests are listed in Table 2. The descent rate for each test was calculated by dividing the distance traveled by the time. The descent rates were further normalized by dividing by the actual mass of the attached weight and multiplying by 5 g to remove any influence from the different masses. The normalized results were inspected and obvious outliers in each group were removed from further consideration. Turbulence from wind caused nearly all of the outliers by creating updrafts and downdrafts or blowing the streamers long distances. The remaining filtered data were averaged and the sample standard deviations were calculated. Since there were only about 10 replicates for most cases, the true standard deviation was estimated at the 90% confidence limit as

$$\bar{x} \pm t_c \frac{s}{\sqrt{n}}$$

where $\bar{x}$ is the sample mean, t_c is the Student-t percentage point distribution, s is the sample standard deviation, and n is the number of data points (Chatfield, 1983).

Results of the tests for different streamer materials are shown in Figure 1. Overall, the results agree well with the descent rate of 2.61 ± 0.16 $m \cdot s^{-1}$ reported previously for fully folded streamers (Kaplow and Jones, 1984). The best performance was clearly from Micafilm at 2.04 $m \cdot s^{-1}$, but cellophane, yellow tracing paper, and DragStrip Mylar were all close behind at about 2.2 $m \cdot s^{-1}$. Bond paper and the other Mylars fared worse at 2.5 to 2.7 $m \cdot s^{-1}$. Crepe paper had the worst performance at 2.80 $m \cdot s^{-1}$, likely due to the lack of pleats, which greatly increase drag for the other streamers.

Results of the tests for different streamer lengths are shown in Figure 2. These results show that length-to-width ratios > 10 provide a definite performance advantage, which agrees with results observed for unpleated Mylar streamers (Barber and Milkie, 1972). Additional testing should be performed to find out if the additional weight or packing space needed for longer streamers has any detrimental effects on their performance.

Although the results presented here offer much information about the performance of streamers, there are additional variables involved in optimizing streamer duration competition. Most notably, the models should be built as close as possible to the optimum mass. If the model is significantly over the optimum mass, it may be advantageous to use a smaller streamer or lighter weight material such as tracing paper instead of Micafilm. The additional altitude gained from a model at optimum mass may be great enough to offset the lower performance of a sub-optimal streamer.

Conclusions

Based on data gathered from a series of drop tests, Micafilm was determined to offer the best performance of the streamer materials tested. Tracing paper, cellophane and DragStrip Mylar showed slightly lower performance, but the lighter weight of these materials could make them useful for models over optimum mass. Increasing the length-to-width ratio > 10 also increases performance, although the optimum ratio could not be determined.

Acknowledgments

I am grateful for the assistance provided by Jennifer Ash-Poole for timing the drop tests. Gary Parker, Assistant Director of Operations and Facilities, allowed access to Byrd Stadium to perform the tests. Dr. John Ondov allowed access to his laboratory for weighing the streamers and attached weights. Mylar® is a registered trademark of DuPont Teigin Films.

References

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Chatfield, C. (1983) *Statistics for Technology: A Course in Applied Statistics*, 3rd ed. Chapman & Hall, New York.

Flanigan, C. (1976) More on Streamer Duration Optimization. *J. MIT Rocket Soc.*

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Table 1. Properties of streamers used for drop tests

Streamer Number	Material	Length (in)	Streamer Mass (g)	Attached Weight (g)	Total Mass (g)
1	crepe paper	40	3.3206	4.8400	8.1606
2	crepe paper	40	3.3267	4.8341	8.1608
3	cellophane	40	3.4974	4.7884	8.2858
4	cellophane	40	3.5272	4.7792	8.3064
5	tracing paper	40	3.0599	4.8558	7.9157
6	tracing paper	40	3.0999	4.8005	7.9004
7	bond paper	40	6.0686	4.8252	10.8938
8	bond paper	40	6.0925	4.8428	10.9353
9	Micafilm	40	4.3412	4.8119	9.1531
10	Micafilm	40	4.2902	4.8380	9.1282
11	ESD Mylar	40	3.5254	4.7713	8.2967
12	ESD Mylar	40	3.5481	4.8160	8.3641
13	1.5 mil Mylar	20	2.5353	4.7755	7.3108
14	1.5 mil Mylar	20	2.5381	4.7602	7.2983
15	1.5 mil Mylar	30	3.7851	4.8543	8.6394
16	1.5 mil Mylar	30	3.8058	4.8169	8.6227
17	1.5 mil Mylar	40	5.0554	4.8907	9.9461
18	1.5 mil Mylar	40	5.0581	4.8193	9.8774
19	1.5 mil Mylar	50	6.3674	4.8576	11.2250
20	1.5 mil Mylar	50	6.3293	4.8498	11.1791
21	1.5 mil Mylar	60	7.5824	5.4080	12.9904
22	1.5 mil Mylar	60	7.5452	5.3870	12.9322
23	DragStrip	40	3.4083	5.4448	8.8531
24	DragStrip	40	3.4520	5.4868	8.9388

Table 2. Descent times, s, for various streamer types. Data not used for later analysis is denoted by a superscript letter giving the explanation.

crepe paper	cello-phane	tracing paper	bond paper	Micafilm	ESD Mylar	1.5 mil Mylar, 20"	1.5 mil Mylar, 30"	1.5 mil Mylar, 40"	1.5 mil Mylar, 50"	1.5 mil Mylar, 60"	DragStrip
6.78	10.09	9.09	9.32	11.18	8.97	6.84	8.90	8.35	8.63	8.29	7.52
8.06	8.55	8.77	9.13	10.61	6.88	8.76[a]	9.13	7.58	9.86	8.17	11.00[a]
7.63	7.77	12.39[a]	7.58	10.95	9.47[a]	9.37[a]	8.87	7.45	13.08[a]	7.01[a]	10.07[c]
7.21	8.09	6.47[a]	7.37[a]	10.57	14.54[c]	7.09	8.05	10.79[a]	3.72[b]	9.33	10.94[a]
5.76[a]	12.25	10.92	12.44[a]	15.66[c]	10.20[b]	7.78	4.76[b]	7.58	9.23	10.21[a]	10.2[a]
6.35[a]	12.36	7.51[a]	9.53	9.40	9.92[a]	6.16	7.61	7.88	4.03[b]	7.92	7.92[a]
7.59	9.57	8.30[b]	8.89[a]	6.30[b]	5.23[b]	8.23	7.66	8.82	3.34[b]	6.59[b]	4.98[b]
3.83[b]	8.57	8.42	8.25	6.49[a]	11.88[a]	3.83[b]	6.43[b]	9.00[a]	8.44	4.26[b]	7.94
3.74[b]	10.19	9.23	8.83	9.76	7.83	4.69[b]	3.39[b]	8.20	8.24	5.25[b]	7.70
6.60	8.13	7.70[a]	7.81	10.47	8.50	8.75	7.29	7.37	11.27[a]	9.89	8.67
8.11	3.83[b]	7.45[a]	9.62[a]	8.78	9.53	7.29	9.30	11.68[c]	5.62[a]	10.52	9.43
7.62		7.39[a]	11.28[a]	10.77	11.03[a]	8.14	10.63	5.34[b]	10.03	11.50[c]	12.67[c]
7.65		9.49	8.32	8.43[a]	8.42	6.54	11.93[c]	6.87	4.48[b]	11.97[c]	9.97[a]
		9.93	7.67	9.31[a]		7.13[a]	6.99		10.54	12.47[c]	7.76
		9.66	4.97[b]	13.58[c]		8.67[a]	11.57[a]		5.23[b]	8.80	10.22[c]
		9.17[b]	6.30[b]			10.7[c]	7.81			3.97[b]	8.98
		6.18[b]				7.47[a]	4.74[b]			6.37[a]	10.53[a]
		9.37				5.91[a]	6.23				8.21

[a] streamer drifted a long distance
[b] streamer hit wall and/or did not fall the entire distance
[c] streamer caught in updraft

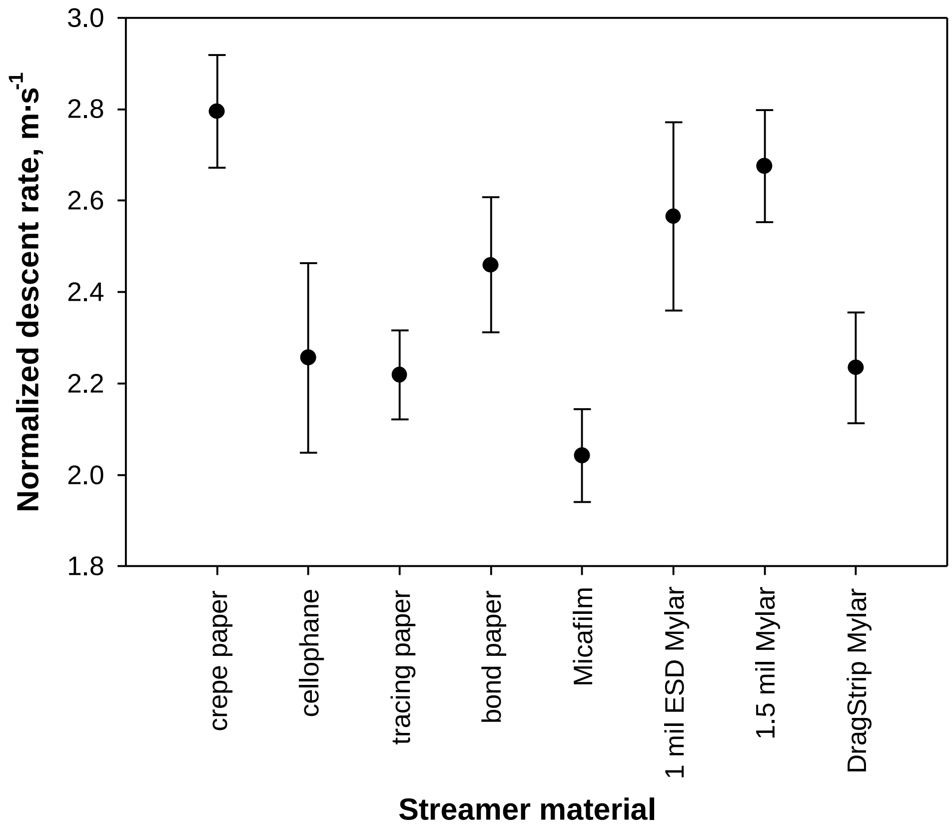

Figure 1. Normalized descent rate vs. streamer material

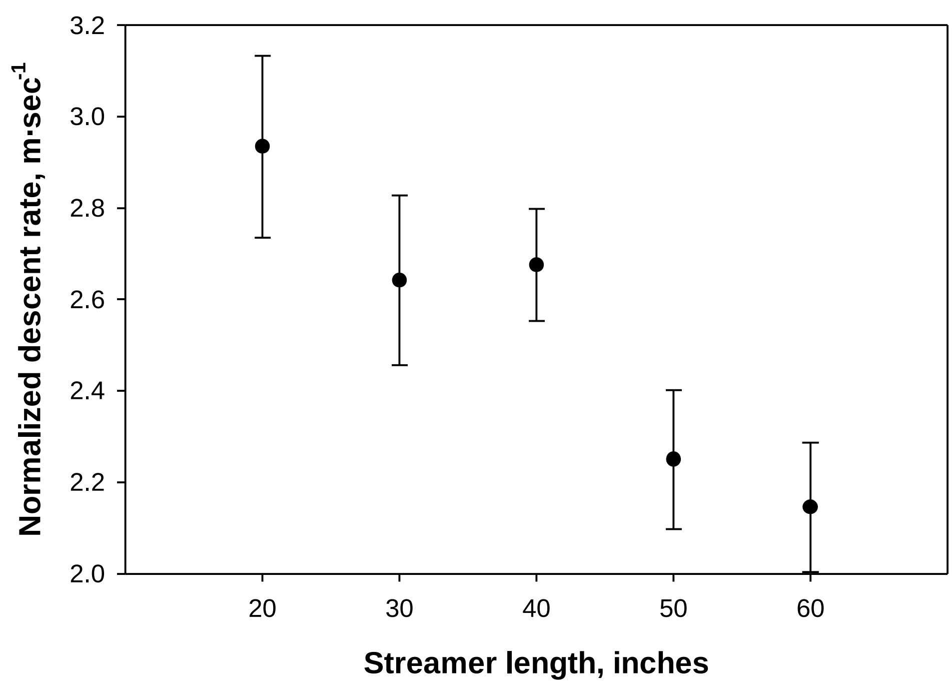

Figure 2. Normalized descent rate vs. streamer length

Appendix – Materials Used

Crepe paper
Pearl Art & Craft Supplies
Rockville, MD
20” x 7.5’, $2.00

Cellophane wrapping paper
Pearl Art & Craft Supplies
Rockville, MD
20” x 12.5’, $4.20

Yellow tracing paper
Pearl Art & Craft Supplies
Rockville, MD
12” x 150’, $7.50

White bond paper
Pearl Art & Craft Supplies
Rockville, MD
12” x 75’, $3.50

Coverite Micafilm
Tower Hobbies
P.O. Box 9078
Champaign, IL 61826
29” x 15’, $26.99

ESD Mylar
donated by Andy Eng

1.5 mil Mylar
Totally Tubular
Box 430
Hamburg, MI 48139
4” x 50’, $5.00

DragStrip Mylar
Eclipse Components
570 Buckeye Drive
Colorado Springs, CO 80919
4” x 40”, $2.25

Total cost of project: approximately $60