

Research Article

Evaluation of Containment Force Variability between Different Grades of Stretch Film

Kyle D. Dunno, Jake Wyns, John Cook

Atlantic Packaging Corporation 12201 Steele Creek Road Charlotte, NC 28273, USA

Publication Date: 25 October 2017

DOI: <https://doi.org/10.23953/cloud.ijapt.318>

Copyright © 2017. Kyle D. Dunno, Jake Wyns, John Cook. This is an open access article distributed under the **Creative Commons Attribution License**, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Abstract Containment force is a measurement often used to qualify stretch films when they are applied to a unit load of packaged product. This measurement records the amount of resistance force a stretch film delivers when being displaced a specified distance. It has been the industry perception there are quality differences between commodity and high-performance grade stretch films. These perceived quality differences are believed to affect the variability between different grades when being examined in a laboratory. In order to evaluate this theory, two different grades of stretch film from two different manufacturers were applied to an instrumented test pallet and the containment force was measured. Results from this study showed there were no statistical differences between the variability of containment forces of different grades of stretch film between the same manufacturers. While the study was limited to only two manufacturers, the results indicated there is less variability between commodity and high-performance grade stretch films than was originally theorized. Additionally, it was observed that a predetermined containment force measurement of 25 lbs. could be obtained through a variety of different stretch wrapping parameters and equipment settings. Many of the developed patterns and settings used would have resulted in load shifting and/or load failures during actual transport. As a result of these observations, it was recommended to use containment force measurements as part of a quality assurance program and not a predictor of success during transportation.

Keywords *Containment force; Stretch film; Unit load*

1. Introduction

Packaged products are transported throughout the supply chain using a variety of complex distribution channels in order to deliver the goods to the consumer (Dunno, 2014). The primary method for distributing goods through the supply chain is to arrange and unitize packaged products onto a pallet for shipment. The most common material used in the transport packaging industry to unitize loads is stretch wrap (Rogers, 2011). Stretch wrap is a ductile plastic film that is wrapped around a unitized load of packaged products. Stretch film can be applied to a unit load either manually or through an automated process. Today, stretch films are engineered and designed to increase load containment and stability of the cargo (Pischel, 2017). Properly stretch wrapped loads begin by defining these parameters: load type, wrapping configuration and distribution environment (Singh et al., 2014). Figure 1 illustrates the different Load Profiles used to describe unitized loads.

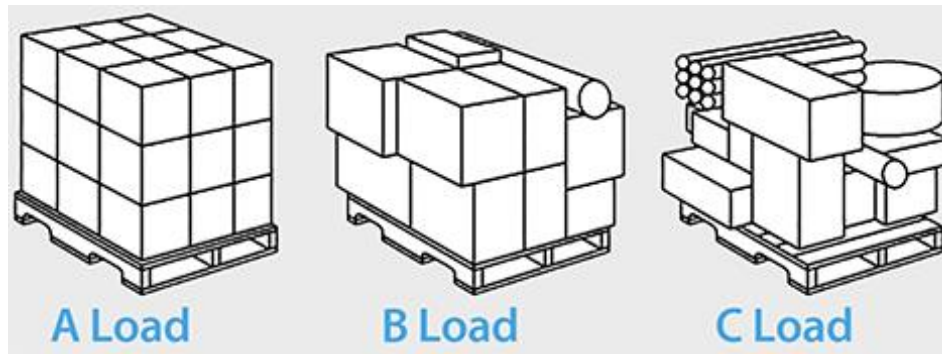


Figure 1: Load profiles (Stretch Film, 2017)

In very general terms, there are two types of stretch film produced and used within the packaging industry to secure loads for transport (Twede and Harte, 2011). These two categories are hand and machine films, which can be produced through a blown or cast extrusion process (Robertson, 2016). Regarding machine films, there are two common grades of stretch film produced, commodity grade and high-performance films. These films have different mechanical properties and can be engineered and designed for specific applications (Packaging Film Lab, 2017). It is presumed the two films would have different operating ranges and variability in performance when comparing commodity and high-performance grade films, but the data and science backing this theory is not readily available for users of stretch film.



Figure 2: Highlight transportable test pallet

One way to evaluate stretch film application is through measuring its containment force. Containment force is a common method used to measure the holding force of stretch film after it has been applied to a load of packaged products. This information can be easily obtained by following the protocol described in ASTM D4649 - Standard Guide for Selection and Use of Stretch Wrap Films (ASTM D4649-03, 2016). In this standard, a force plate and gauge are used to measure the containment force of the unit load. These systems can range from a simple steel plate or finger style tool with a force gauge to a complex system capable of measuring various film properties. One such complex system that can be used for evaluating stretch film application is the Highlight Transportable Test Pallet (Highlight Industries, Wyoming, and MI). Figure 2 illustrates the transportation test pallet system. This system is capable of collecting and measuring different stretch

film properties, including puncture, containment force, and compressive force, which are beneficial to both the manufacturer and end user of stretch films (Portable Electronic Equipment, 2017). In addition to determining film properties, this style of equipment can also be used as a quality control measurement device. As the equipment is designed to evaluate stretch film material properties, it is critical to understand the variability in the equipment used to evaluate these parameters.

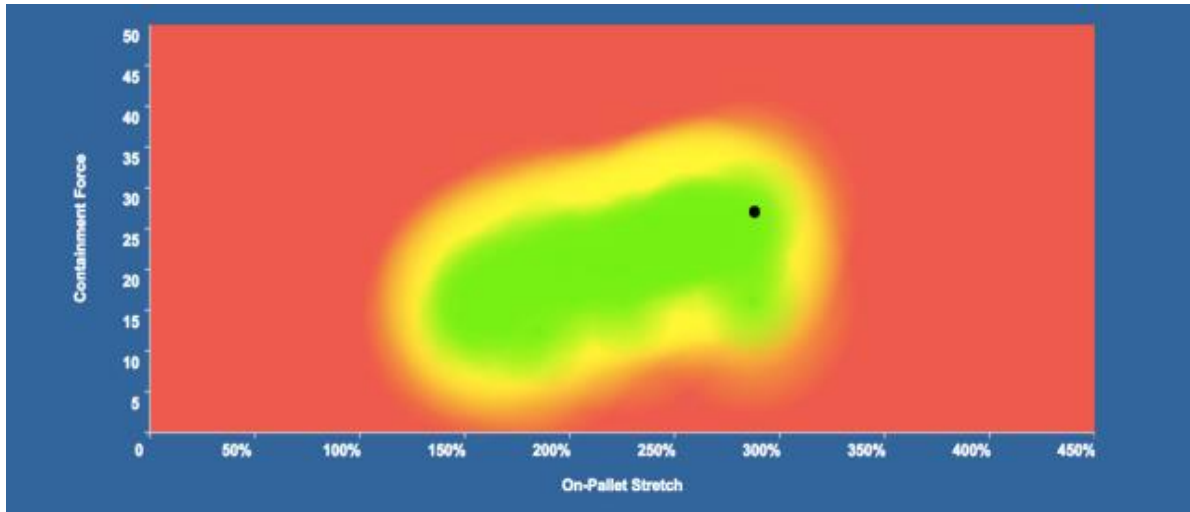


Figure 3: Generalized heat map for high-performance stretch film

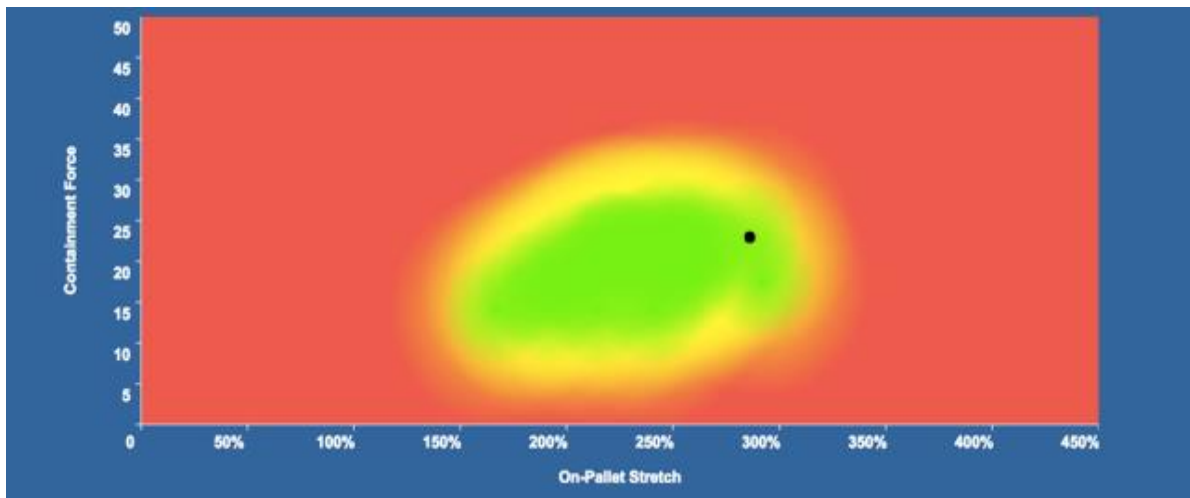


Figure 4: Generalized heat map for commodity grade stretch film

Containment force measurements can be useful during auditing and quality control, but lack correlation to field performance or application. The containment force is a quantifiable test method, but obtaining a specified containment force only indicates the system is in control. It doesn't indicate or predict the success of a wrapping pattern or film selection. As a result, the correlation between containment force and performance in the field needs to be investigated further as this is a critical knowledge gap that exists in the stretch film market.

The objectives of this research study were to evaluate the variation of the observed recordings and to determine the different wrap pattern combinations that can produce a similar containment force reading.

2. Materials and Methods

This evaluation involved two high-performance (HP) stretch films and two commodity grade (CG) stretch films, produced by a cast extrusion process. The HP films evaluated in this study were thinner in gauge than the corresponding CG stretch films. HP films for this study were categorized as having the ability to stretch beyond 275% ultimately having a wider working region of the film. Commodity films were described as having a lower operating and performance window. Figures 3 and 4 are developed heat maps which illustrate the general working regions for the two different grades of stretch film. The stretch films designated for this project are described in Table 1.

Table 1: *Stretch film properties*

Manufacturer	Material ID	Thickness (gauge)	Basis Wt. (GSM)	Roll Width (in.)
A	HP 1	51	50.3	20
B	HP 2	55	55.5	20
A	CG 1	70	72.4	20
B	CG 2	70	72.3	20

The selected films were applied to the perimeter of the Highlight Transportable Test Pallet using a Synergy 4 Highlight Stretch Wrapper (Highlight Industries, Wyoming, MI). Table 2 displays the stretch wrapper setup parameters used for this evaluation. Upon successful wrapping of the test pallet, the system was activated to perform the ASTM D4649 containment force test (ASTM D4649-03, 2016). The test is performed by extending a 6" diameter piston outward 4" at a constant rate. Upon full extension of the piston, the maximum containment force was obtained and recorded by the data acquisition system. This test sequence was performed ten times per film variable.

Table 2: *Stretch wrapper configuration*

Stretch Wrapper Parameters	
Number of top wraps	3
Pre-stretch (%)	250
On-pallet stretch	Positive
Turn table speed (rpm)	20
Carriage speed (%)	60
Number of revolutions	14

The stretch film identified as HP 1, was used to compare the different wrapping patterns and configurations to create a pre-determined containment value of 25 lbs. For this portion of the research project, the same roll of stretch film was used throughout the experiment. Here, as previously described earlier, the HP 1 stretch film was applied to the perimeter of the Highlight Transportable Test Pallet using a Synergy 4 Highlight Stretch Wrapper. Upon the completion of wrapping, the maximum containment force was obtained by the data acquisition software.

3. Results and Discussion

Results indicated the Highlight Data Acquisition Test Stand produced repeatable results which could be used to ensure quality control parameters of stretch film. To compare the variability between the two different grades of stretch film materials, a F-test for the Equality of Two Population Variances was computed with the data sets collected. Results from this analysis showed no statistical differences were observed between the variability of containment force for the two different grades of stretch films. Given the nature of the terminology used to describe these films, it was perceived commodity grade stretch films would have higher variability in the stretch parameters as compared to a higher performance stretch film. Observations from this study showed there was no statistical

difference in the variance between the two grades of materials, regardless of the terminology used to describe the film. Table 3 and Figures 5 and 6 show the results obtained from this analysis.

Table 3: Load containment measurements

ASTM Max Load Containment (lbs.)				
Test No.	Manufacturer A		Manufacturer B	
	HP	CG	HP	CG
1	21.0	23.5	20.7	20.1
2	21.5	23.4	21.5	20.9
3	21.8	23.2	20.7	20.5
4	21.6	23.4	23.1	20.5
5	23.1	22.9	20.8	20.6
6	22.0	24.4	21.6	20.4
7	21.7	23.7	22.7	20.2
8	22.6	23.2	20.7	19.7
9	21.8	23.0	20.8	19.9
10	21.5	23.0	20.7	19.9
Average	21.9	23.4	21.3	20.3
Std. Dev.	0.6	0.4	0.9	0.4

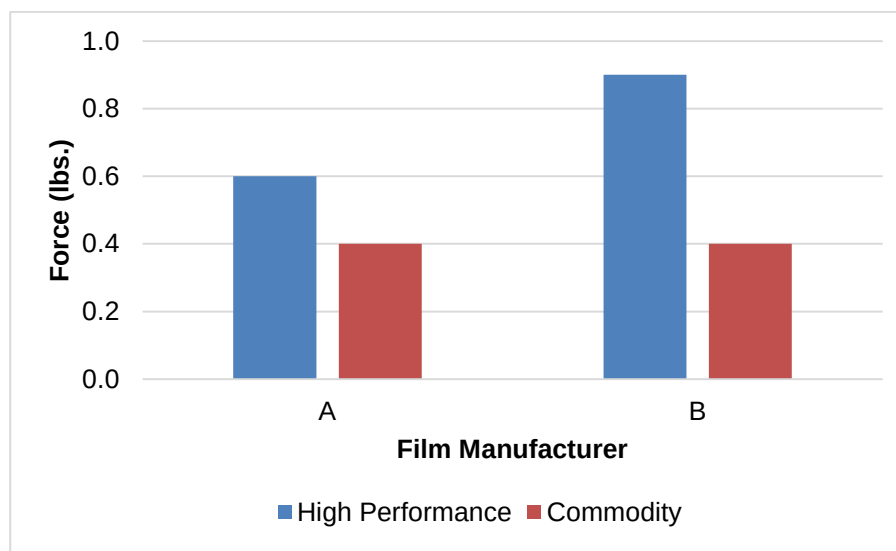


Figure 5: Standard deviation in load containment measurements

In addition to the containment force, the transportable test pallet as part of this study also measured the compressive forces of the stretch films. The high-performance films were of thinner gauge as compared to the commodity films evaluated in this study. The thinner gauge high-performance materials are being engineered to provide the better performance while additionally providing a more sustainable approach to unitizing loads. The measurements recorded illustrated the thinner gauge high-performance films could provide similar type compressive forces as those of thicker gauge materials (Figure 6). This was a key observation during this study as the transport industry continues to increase its usage of thinner gauge high-performance stretch films (Pischel, 2017). As such, it will be imperative for users of stretch film to understand how high-performance films correlate with commodity grade films.

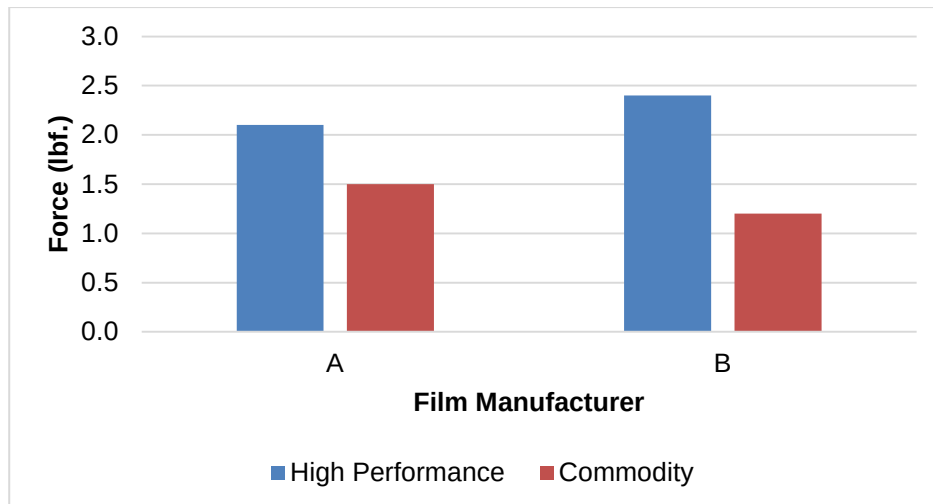


Figure 6: *Compressive force of stretch films*

Table 4: *Wrapping configurations executed using HP1 Stretch Film*

Pre-Stretch (%)	Pallet Stretch (%)	Top Wraps	Cut & Weigh (oz.)	Revolutions	Tension Force	ASTM Force (lbs.)
150	242	3	3.8	14	6.40	25.3
150	202	4	4.7	15	5.90	24.3
150	167	5	5.6	16	5.40	24.8
150	158	6	6.3	17	5.20	25.3
175	237	3	3.9	14	6.00	25.4
200	273	2	3.5	13	6.05	25.3
200	233	3	4.0	14	5.60	24.8
200	216	4	4.7	14	5.35	25.3
200	205	5	5.2	14	5.20	25.6
225	253	3	3.7	14	5.40	25.6
250	313	2	3.0	13	5.90	24.6
250	270	3	3.6	14	5.35	26.8
250	254	4	4.0	15	5.20	24.1
275	284	3	3.4	14	5.20	25.8
300	315	2	2.9	13	5.35	24.7
300	307	3	3.2	14	5.10	24.5
300	297	4	3.5	15	5.00	24.4

The containment force is a quantitative measurement of the system but is not always an indicator of application performance when looking at the performance of the load in the field. The containment force values are based on the number of film revolutions applied to the load and the tension at which the films are applied to the load. As a result of this, there were numerous patterns and wrapping configurations developed to generate the same containment force, but all may have different results during transport. Table 4 displays the number of wrapping configurations capable of producing a containment force of 25 lbs. In total, 17 different wrapping configurations were utilized in order to produce a maximum containment force value of approximately 25 lbs. Although certain wrapping

configurations displayed may be egregious, if obtaining a specified containment force is part of a quality assurance, these loads would be acceptable based on reaching a specified predetermined containment force value.

4. Conclusion

Conducted was an examination of the variability between two different grades of stretch films. An instrumented transportable test pallet was employed to measure containment force of the stretch films after application. Results showed the transportable test pallet was capable of reproducing repeatable results that could be used for quality assurance and control by stretch film manufacturers and end users.

Comparing the two different grades of film, no statistical difference existed between the variability of containment force across the samples evaluated. These results, which are only based on the data collected from this study, indicate there was not higher variability in containment force for the common grade stretch films, which was the perceived notion. Further research could be completed to compare variability of commodity and high-performance grade stretch films to incorporate multiple production runs and production locations.

The compressive forces measured during this analysis showed the high-performance stretch films compared favorably with the commodity stretch films. With the high-performance stretch films being thinner in gauge, the results from this data set indicate it is possible to obtain the same types of compressive forces as those offered by thicker gauge commodity films. Additionally, the thinner films are a more sustainable approach to unit load stability by reducing the total stretch film volume usage.

In addition to evaluating the variability of containment force, a number of different wrap configurations and patterns were developed in order to produce a particular containment force value of 25 lbs. The containment force value is a quantitative measurement, but does not necessarily correlate to performance during transport. To produce a maximum containment force value of 25 lbs., seventeen different wrapping patterns and/or configurations were employed. At this stage, the wrapping patterns were not compared to field performance, only showing the reader there are numerous configurations to produce a specified containment force value. This is valuable as it shows if only using containment force as a metric for performance, the stretch film user could potentially be unaware of changes in wrapping patterns which could potentially lead to a decrease in load stability.

References

ASTM D4649-03. 2016. *Standard Guide for Selection and Use of Stretch Wrap Films*. ASTM International, West Conshohocken, PA. Available from: <https://www.astm.org/Standards/D4649.htm>

Dunno, K. 2014. Effects of transportation hazards on package performance and food product shelf life. Available from: http://tigerprints.clemson.edu/all_dissertations/1432

Pischel, K. 2017. *Elimination of Shipping Damage through Stretch Film Optimization*. International Safe Transit Association TransPack Forum, Orlando, FL.

Packaging Film Lab - Atlantic Packaging. 2017.
Available from: http://www.atlanticpkg.com/consulting/film_lab

Portable Electronic Equipment - Highlight Industries Inc. 2017.

Available from: <http://www.highlightindustries.com/portable-electronic-equip>

Rogers, L.K. 2011. Keeping it together. *Modern Materials Handling*, pp.32-35.

Robertson, G.L. 2006. *Food Packaging: Principle and Practice*. Boca Raton, FL.: CRC Press.

Singh, J., Cernokus, E., Saha, K. and Roy, S. 2014. The effect of stretch wrap prestretch on unitized load containment. *Packag. Technol. Sci.*, 27, pp.944-961.

Stretch Film-Kyana Packaging Solutions. 2017

Available from: <http://www.arbaughmarketing.com/SCStretchFilm2.html>

Twede, D. and Harte, B. 2011. *Logistical Packaging for Food Marketing Systems*, in food and beverage packaging technology. 2nd ed. Coles, R. and Kirwan, M. (eds.), Oxford, UK: Wiley-Blackwell, pp.85-105.