Evaluation of the Stress-Energy Methodology to Predict Transmitted Shock through Expanded Foam Cushions

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ABSTRACT

Mechanical stresses experienced by packages in the distribution environment include shock and vibration amongst several others. The destructive effects of these hazards can typically be restricted by using cushioning materials to help protect fragile goods during distribution. ASTM D 1596 is the conventional standard used to determine shock absorbing performance of a cushioning material for a given combination of static loading, thickness, and drop height. This industry-accepted standard, however, requires significant amounts of transmitted shock data and can be expensive with respect to costs associated with testing and materials amongst others. Alternate stress-energy-based methodologies, developed in the past decade, recommending a considerable reduction in the number of drop tests while providing the ability to predict transmitted shock for any drop height, static loading as well as cushion thickness, are evaluated in this study for their stated accuracy. Based upon an in-depth evaluation of dynamic cushion curves for closed cell moldable foams generated using ASTM D1596, this research evaluates the accuracy of the proposed methodology in relation to the prediction of transmitted shock. Results show that the stress-energy methods while saving time in predicting transmitted shock, produce higher degrees of error than the ±5 % previously stated. In addition, they cannot predict behavior of cushions, and transmitted shock at high drop heights and static loadings with thin cushions, where only the measured values are accurate.

INTRODUCTION

Goods distributed through the supply chain are commonly exposed to mechanical stresses in the form of shock and vibration. Cushioning materials typically tend to provide economical solutions to counteract these forces while ensuring safe passage of the goods through the supply chain. In case of fragile products, such as sensitive electronic products that are particularly susceptible to mechanical stresses, cushioning is typically placed inside a shipping container such as a corrugated fiberboard box, encompassing the product within. The cushion absorbs a proportion of the kinetic energy arising from the distribution of related hazards by deforming to levels below those, which can cause damage to the product being carried within. Besides the cushioning function, cushions are also commonly used to immobilize the products inside a shipper.

Some of the key criteria used in the selection of cushioning include its effectiveness against shock, vibration, resilience, cost (material and productivity), effect of temperature and humidity, effect on size of external shipper, disposal, recycling, and environmental issues. In theory, a cushion can be modeled as a spring in a spring-mass model, with the product representing the mass [1]. With respect to vibration, depending upon its thickness, load-bearing area, and the vibration frequency, a cushion may have no influence, or may amplify or isolate the incoming vibration frequency. However, the primary purpose of a cushion is to absorb mechanical stresses resulting from shocks occurring during distribution. The effect of vibration on the response of cushions is not discussed in this paper.

A typical dynamic cushion curve is illustrated in Fig. 1. It represents the dynamic performance of a cushioning material for a given combination of thickness and drop height. The horizontal axis represents a range of static loadings that products of different weights might apply to the cushioning material. The vertical axis represents the transmitted shock experienced by the product when it is subjected to an impact on the cushion. These cushion curves are often presented for both the first impact and multiple impact (average of drops 2–5) data. It is common to include data for several cushion thicknesses from a constant drop height on a single plot.

If the product fragility (G) is known, the following procedure can be used to determine the amount of functional cushioning material, which would provide adequate protection for the packaged item against shocks. The functional cushioning material is referred to as that portion of the cushion area, which directly supports the load, and absorbs the shock during impact. In order to calculate the cushion area, the following procedure is used:

1. Consider a product that needs to be cushioned using end-caps or corner protectors. Assume the fragility of the product to be 40 *G*.
2. Using the set of cushion curves (Fig. 1), draw a horizontal line through the transmitted shock level of 40 *G*.
3. All cushion curves that either intersect or lie below this line are suitable to provide shock levels at or below 40 *G*.
4. So for example, a cushion designer can select the least available thickness of 1.5 in.
5. The next step is to determine the cushion bearing area.

Using the vertical lines dropped from the point of intersections between the 1.5 in. cushion curve and the deceleration of 40 *G*, an upper and lower bound of static loadings can be selected.

The largest static loading of 1.2 psi shown in Fig. 1, allows the designer to use the smallest amount (area) of cushion that will provide the required shock protection.

ASTM D1596 (Standard Test Method for Dynamic Shock Cushioning Characteristics of Packaging Material) covers an industry-accepted procedure for obtaining dynamic shock cushioning characteristics of packaging materials achieved from dropping a weighted and guided platen assembly onto a stationary cushion sample [2]. The dynamic cushion curves can be used to determine minimum thickness, static loading, and bearing area, all of which are essential in the design of a cushion.

Although extensively adopted by the cushion manufacturers to develop cushion curves, the ASTM D1596 methodology requires extensive resources and time. According to a recent, study, generation of a full set of cushion curves for a range of drop heights and seven cushion thicknesses requires approximately 10 500 sample drops and over 175 h of test time [3]. The need to simplify and reduce the testing required generating cushion curves have been made in several past studies.

ASTM D1596 requires a one minute interval between drops on the same cushion. Generally manufacturers of cushioning materials test the transmitted shock levels from 18 to 48 in. in 6 in. increments, and at five different static loadings. As many as five thicknesses from 1 to 6 in. may be presented on a plot for a given height. Therefore, six drop heights, six thicknesses, five static loadings, and five drops at each static loading will result in 900 drops for a single sample test. If five replicate drops are done at each transmitted shock condition, this would result in 4500 drops, requiring approximately 100 h of data collection. However, in most cases, only one sample per data condition is used, thereby requiring much less time and number of impacts than what has been previously cited [3].

A dynamic stress-strain curve method of consolidating all the cushion curves for a particular material into a single relationship was shown to work for resilient closed-cell foams by Burgess [4]. This study verified that for a range of drop heights (12–48 in.) and cushion thicknesses (1–5 in.), the stress-strain method could predict *G* values with great accuracy. The results from this methodology also provide information on the maximum cushion strain incurred in the impacts, whereas the conventional curves do not. The predicted strain values for closed-cell foam were confirmed by experimental methods using both double integration of the shock pulse and a high-speed camera. The actual peak strain values for high-end static loadings (nearing 3 psi) were observed to be within ±5 % of the predicted values [4].

A dynamic stress versus energy density methodology proposed by the same researcher, in a later publication, also validated that complete sets of cushion curves could be generated using only 10–20 drops, and these could predict transmitted peak *G* results with an accuracy of ±5 % [5]. The dynamic stress versus energy curves were proposed to be deduced directly using information taken off the published cushion curves or by conducting a limited number (10–20) of shock tests. Energy density, a measure of the severity of the drop, was defined as (static stress x drop height)/ (cushion thickness) or *sh*/*t* and stress, a measure of the cushions' response to it as (peak *G x* static stress) or *Gs*. The real usefulness of this method was proposed to be the stress versus energy relationship, a property of the material, which could replace all of the cushion curves while allowing for the predictability of the transmitted shock (*G*'s) for any situation. Both of the approaches discussed above were accepted to have a trade-off between accuracy and effort. Cushion curves generated using the ASTM D1596 procedure, however extensive, were agreed to be more accurate.

A recent study provides improvements to the methodologies discussed above [3]. It proposes a simplified method for manipulating and displaying the stress-energy equation using a common spreadsheet data analysis tool. The underlying relationship between the dynamic energy *(sh/t)* and dynamic stress *(Gs)* is described as $y = ae^{bx}$, where *y* is the dynamic stress and *x* is the dynamic energy. The constants, *a* and *b*, are dimensionless values that describe the material properties of the cushion [3].

Another study evaluated the possibilities of reducing the sample size needed to develop dynamic cushion characteristics through reductions in the numbers of energy intervals, replicates per energy level and drops performed on each sample [6]. The study concluded that three energy levels produced statistically valid cushion curves as compared to those created using a full set of data with careful consideration recommended when picking the extremes of the energy levels. The study concluded that though the three energy level model predicted lower shock levels as compared to the cushion curve data, they were found to be acceptable within lab-tolaboratory variations. It also concluded that performing five drops on the same sample was not necessary to predict behavior for multiple impacts.

This paper studied an in-depth comparison of dynamic cushion curves for closed-cell moldable foam (ProLam^{TM} Laminated Polyethylene Plank) generated using ASTM D1596 and the various stress-energy methodologies. The data for the stress-energy methodology was computed using the various methodologies identified in previous studies [3–6].

The objective of this study was to measure the accuracy of the various methodologies in relation to predicting of transmitted shock, and to compare to data actually collected using ASTM D1596, and to determine associated errors.

METHODOLOGY

Dynamic Cushion Characteristics Using ASTM D1596

Dynamic cushion curve characteristics were generated using data collected from ASTM D1596 (traditional method). Cushion curves were created for 1.7 pcf ProLam^{TM} Laminated PE Plank using the following variables:

a. Five cushion thicknesses of 1, 1.5, 2, 3, and 4 in.
b. Five static loadings of 0.2, 0.5, 1, 1.5, and 2 psi.
c. Six drop heights of 12, 18, 24, 30, 36, and in.

Stress-Energy Method

Data from eleven energy levels was selected from the traditional method and computed as shown in Table 1.

Linear Regression Approach—To predict the dynamic stress values from the energy values, we used the following exponential relationship:

$$y = ae^{bx} \qquad (1)$$

where:
y=dynamic stress=Gs,
x=dynamic energy=sh/t,
a and b=dimensionless values.

Once the coefficients a and b are found, the predicted transmitted shock (G) can be calculated for different drops.

Using all 11 energy levels (sh/t=6, 9, 12, 15, 18, 21, 24, 27, 30, 33, and 36), the regression yields the coefficients in Table 2 for each of the predicted shocks (G) at each drop (1–5). In addition the variation (R^2 and the standard error of the regression for each model is presented. Here G1 is the predicted shock after first drop, and G5 is the predicted shock after the fifth drop.

All R^2's are above 90% so the exponential function used in Eq 1, is a good fit. For every combination of the values of s, h, and t and using the constants from above, the predicted shock values were also estimated using the stress-energy method. These were then compared to the data from the data obtained experimentally using ASTM D1596.

Reduction of Energy Levels—It is of interest to further reduce the amount of drop test data. One way to achieve this is by using a smaller number of energy levels, i.e., sh/t values. A regression analysis was performed to predict G values by only using 3, and 5 energy levels respectively. In both cases values of sh/t were chosen where the range of sh / t was as large as possible, and had the highest R^2 values (least error). The optimal choices for five levels were 6, 12, 21, 30, and 36 and for three levels were sh/t=6, 21, and 36.

The corresponding coefficients for determining the predicted shock by stress-energy method are shown in Tables 3 and 4.

As would be expected, using less data for the predictions resulted in smaller values for R^2. Nevertheless, the models fit well (R^2=88.8 % with five energy levels and R^2=86.8 % with three energy levels).

RESULTS

As discussed in the Introduction of this paper, the most conservative selection of the thickness of cushion is made by identifying the cushion curve that either intersects or lies below the fragility (deceleration) line. This ensures that the product will not experience a shock, which will cause damage to it. In analyzing the effectiveness of the stress-energy method for selecting the appropriate cushion thickness, three cases can occur. The first, and most desirable case, is that both the traditional ASTM method and the stress-energy method select the same cushion thickness. This case is designated as an "ASTM" or "same pick." The case where the stress-energy method selects a cushion incrementally thinner than the traditional method is designated as a "thin pick." A thin pick jeopardizes the product (likely damage) by selecting less than the required amount of cushion. The case where the stress-energy method selects a cushion incrementally thicker than the traditional method is designated as a "thick pick." Although a thick pick will adequately protect the product, it is potentially wasteful from a cost and package volume standpoint. The designation and analysis concept is explained in more detail below.

Figure 2(*a*) shows an example of a traditional or same pick of a 1.5 in. cushion for the given shock level (y) by curves generated using "traditional" ASTM D1596 or the stress-energy method.

Figure 2(*b*) shows an example of a thin pick. In this case, the cushion curves estimated using the stress-energy method is too aggressive. At least the 1.0 and 1.5 in. curves are shifted lower than the same curves estimated using the traditional ASTM method as per Fig. 2(*a*). For the given value y, the cushion selected is 1.0 in. This is thinner than would have been selected by the traditional ASTM method.

Figure 2(*c*) shows an example of a thick pick. In this case, the cushion curves estimated using the stress-energy method are conservative. At least the 1.5 and 2.0 in. curves are shifted lower than the same curves estimated using the traditional ASTM method. For the given value *y* the cushion selected is 2.0 in. This is thicker than would have been selected by the traditional ASTM method.

Past research has proposed that the stress-energy method has an "accuracy of ±5 %" [5]. To test this proposition we define the accuracy of a set of stress-energy curves as the proportion of any given *G* values within a standardized range that do not result in a same pick. The standardized range is defined as the range from the lowest point on the uppermost traditional ASTM cushion curve (1.0 in.) to the lowest point on the lowermost traditional ASTM cushion curve (3.0 in.). Because the methodology in this paper allows to differentiate between two types of picks that are not *same picks* (*thin and thickpicks*) the measure of accuracy is further differentiated. Figure 3 shows a conceptual representation of the accuracy analysis.

The actual calculation of accuracy values was accomplished by taking the difference between the minimum deceleration values for
the ASTM and stress-energy curves for a given cushion thickness for each drop height and number of energy levels and expressing it as a percentage of its standardized range. For example, the value of 22.0 in part a of Table 5, for drop height of 12 in, was calculated as

Minimum ASTM curve deceleration value= 30.3
Minimum stress-energy curve deceleration value= 35.3
Difference = − 5.20
Lowest point on the uppermost traditional ASTM cushion curve(1.0 in.) = 30.3
Lowest point on the lowermost traditional ASTM cushion curve(4.0 in.) = 6.64
Difference = standardized range = 23.6
Accuracy value= − 5.20/23.6 X 100 = 22.0 %

The value of 22.0 % was the highest difference for the set of curves analyzed for the first drop (G1) at a height of 12 in. and 11 energy levels. Each set of curves consisted of five cases (i.e., 1.0, 1.5, 2.0, 3.0, and 4.0 in.) for drop heights from 12 to 30 in. and three cases (i.e., 2.0, 3.0, and 4.0) for drop heights of 36 and 42 in. Positive values represent the worst-case percentage of selections that would be a thick pick based for a given shock value based on the standardized range. A negative accuracy value represents a thin pick percentage. The analysis was performed using the first drop (G1) only data across a range of drop heights from 12 to 42 in. Results were collected for stress-energy curve sets generated from 11, 5, and 3 energy levels. These results are shown in part a of Table 5. A comparable set of results for the average shock from the second, third, fourth, and fifth drops (average 2–5) data are shown in part b of Table 5.

Overall, the results show that for the 1.7 pcf ProLam^{TM} Laminated PE Plank material tested, the accuracy of the stress-energy method is much lower than previously predicted (more than ±5 %). Over *the range of data and conditions that were analyzed, the worst-case percentage of thin* picks was 27.5% and the least worst case was 0.00 %. The worst-case percentage for thick picks was 21% and the least worst case was 0.00%. This seems to indicate that overall the stress-energy method is biased towards selecting cushions that are *too thin* when compared to the traditional ASTM method. However, under specific conditions results vary. For example:

- As drop height increases, possible number of thin picks decreases and the number of thick picks increases.
- As the number of energy levels used for predicting *G* decreases, the number of possible *thin picks* decreases while the possible thick picks increase on average, yielding a more conservative selection.

- The trends in the first drop (G1) data are similar to those in the multiple (average second to fifth drop data: G2–G5), but with slightly higher average thin pick values and slightly lower average thick pick values.

DISCUSSION

The results from this study indicate that the stress-energy method for generating cushion curves is more prone to deviate from the ASTM D1596 method than was previously thought. Far from being in the ±5 % range, the difference can be as high as +27.5 % to −21.0 % depending on the circumstances. We concede that part of the problem with a direct comparison of our results with previous research is a lack of information in the exact materials and calculation techniques used in previous research. The results show that the accuracy calculation method used in this study will allow future short cuts to time consuming cushion curve generation to be evaluated more explicitly in future research.

In addition to the error issues the time required to develop a complete set of cushion curves (six drop heights, six thickness, and five static loadings) is usually less than a week.

CONCLUSIONS

- The errors associated with predicting transmitted shock using the stress energy methods are much higher than previously reported levels of ±5 % range. This study concludes the difference between predicted and actually measured transmitted shock to be as high as +27.5 % to −21.0 %.
- The errors of predicting transmitted shock using stress-energy method can be much higher for thin cushions, at high drop heights and static loadings. This is due to the fact that these cushions “bottom out” and release all trapped air during the impact and transmitted shock levels are extremely high.
- The errors in this study are measured using closed cell polyethylene cushions which show a higher degree of resiliency. The errors will increase for other types of paper and starch based foams that are more sensitive to slight changes in temperature and humidity. This is based on data presented on cushioning performance of paper [7] and starch [8,9] based cushioning materials and the effect of humidity on their performance. Most of these materials also show a higher degree of variation in transmitted shock characteristics in additional samples or replicates tested under the same loading conditions [9]. Paper and starch based cushioning materials are also both hygroscopic and therefore their performance affected by high temperature and humidity [9].
- Time associated with collecting data using ASTM D1596 is appropriate and beneficial, since it does not result in large errors based on stress-energy prediction models.

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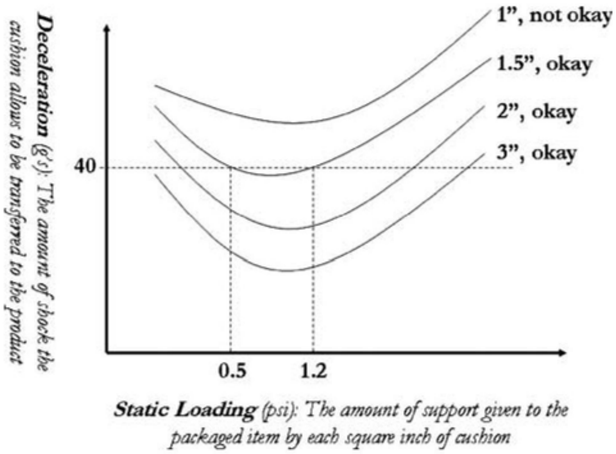


FIG. 1—*Typical dynamic cushion curve.*

TABLE 1—*Data selected using ASTM D1596 for PE cushions.*

s	*h*	*t*	*sh*/*t*	G1	G2	G3	G4	G5
0.2	30	1.0	6	84.94	88.41	89.54	90.01	90.54
0.5	12	1.0		32.93	35.17	35.84	36.41	36.26
0.5	18	1.5		37.73	38.74	39.60	39.71	40.88
0.5	24	2.0		37.41	39.70	40.68	40.06	40.97
0.5	36	3.0		37.95	40.47	41.05	41.23	41.87
0.5	18	1.0	9	50.94	52.79	53.83	53.20	52.89
0.5	36	2.0		52.50	55.73	57.07	56.21	56.30
1.0	18	2.0		24.74	26.53	26.64	27.26	26.90
1.5	12	2.0		17.71	19.15	19.94	20.17	19.98
1.5	18	3.0		19.56	21.61	22.35	22.35	22.45
0.5	24	1.0	12	69.32	70.38	70.78	71.46	71.78
1.0	12	1.0		30.27	31.30	31.84	33.17	31.98
1.0	18	1.5		32.96	35.81	34.87	36.20	36.91
1.0	24	2.0		36.58	35.08	36.50	36.09	37.02
1.0	36	3.0		38.35	41.34	41.90	42.67	42.54
0.5	30	1.0	15	89.22	93.60	93.64	95.01	95.71
1.0	30	2.0		46.28	50.02	51.48	52.22	53.30
1.5	30	3.0		34.52	39.83	39.26	40.02	40.47
2.0	30	4.0		27.81	30.05	31.53	31.41	31.70
2.0	15	2.0		26.03	32.90	33.39	34.31	34.09
1.0	18	1.0	18	53.14	50.22	55.00	52.98	51.55
1.0	36	2.0		60.59	61.91	64.48	66.41	64.55
1.5	12	1.0		36.00	39.36	39.08	38.66	39.12
1.5	18	1.5		44.26	49.36	51.41	51.17	51.32
1.5	36	3.0		43.03	48.05	49.43	50.48	49.55
0.5	42	1.0	21	137.37	156.36	155.47	163.03	158.42
1.0	42	2.0		71.69	76.88	76.93	77.51	79.93
1.5	42	3.0		55.12	60.47	64.31	67.35	68.14
2.0	42	4.0		81.16	112.90	127.27	127.27	137.66
2.0	21	2.0		50.48	56.60	60.03	61.21	60.75
1.0	24	1.0	24	76.92	78.66	74.83	79.18	81.43
1.5	24	1.5		66.89	74.45	75.39	77.18	79.04
2.0	12	1.0		44.95	48.37	46.75	49.20	49.20
2.0	24	2.0		52.23	58.72	60.32	62.10	64.00
2.0	36	3.0		56.65	57.08	64.82	63.98	65.84
1.5	18	1.0	27	74.79	83.52	83.21	83.39	86.40
1.5	36	2.0		106.62	107.94	106.76	108.20	101.17
2.0	27	2.0		68.36	76.37	79.08	80.17	83.45
1.0	27	1.0		117.06	120.58	119.83	119.01	121.50
1.5	27	1.5		85.92	99.28	99.93	105.34	102.31
1.0	30	1.0	30	107.22	112.65	123.02	119.84	112.98
1.5	30	1.5		100.26	112.68	114.20	115.68	117.51
2.0	30	2.0		81.60	91.73	95.61	95.93	100.19
3.0	10	1.0		54.99	59.07	64.49	66.07	63.55
3.0	30	3.0		64.10	74.72	78.84	74.38	79.72
2.0	33	2.0	33	93.40	112.49	118.48	120.52	123.07
1.0	33	1.0		147.64	159.83	163.51	167.16	167.52
1.5	33	1.5		111.38	136.93	139.16	146.31	142.70
3.0	33	3.0		81.95	102.48	103.51	107.01	111.90
3.0	11	1.0		45.45	65.67	68.73	68.99	71.09
1.0	36	1.0	36	144.62	173.45	177.71	181.15	181.81
1.5	24	1.0		118.43	130.17	134.27	136.49	140.65
1.5	36	1.5		142.20	149.95	165.21	167.41	173.83
2.0	18	1.0		91.75	98.56	104.48	102.48	108.16
2.0	36	2.0		99.39	112.66	116.11	122.25	122.49

TABLE 2—*Regression data for drop heights using eleven energy levels.*

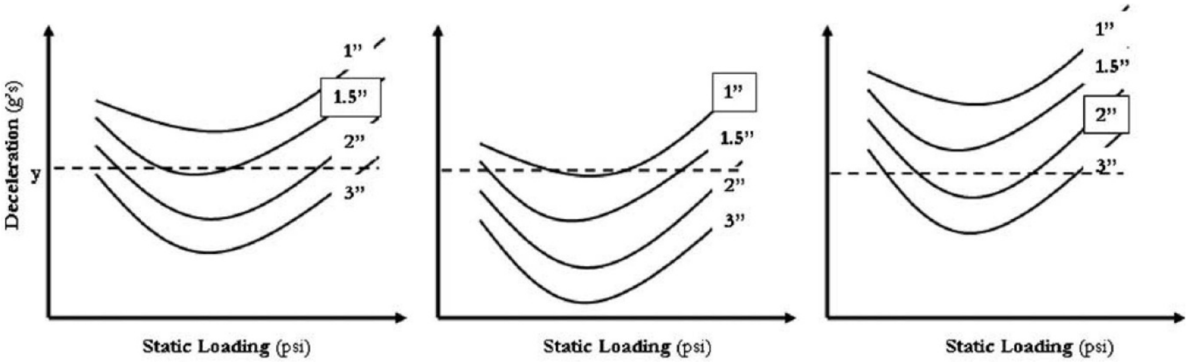
	Constant			
Drop	*a*	*b*	R^2	Std Error
G1	13.8	0.079	0.929	0.210
G2	14.2	0.082	0.916	0.239
G3	14.4	0.082	0.911	0.249
G4	14.5	0.083	0.912	0.249
G5	14.5	0.083	0.907	0.258

TABLE 3—*Regression data for drop heights using five energy levels.*

	Constant			
Drop	*a*	*b*	R^2	Std Error
G1	13.3	0.079	0.921	0.267
G2	13.8	0.081	0.901	0.309
G3	13.9	0.082	0.895	0.326
G4	14.0	0.082	0.896	0.324
G5	14.1	0.083	0.888	0.338

TABLE 4—*Regression data for drop heights using three energy levels.*

	Constant			
Drop	*a*	*b*	R^2	Std Error
G1	13.3	0.077	0.908	0.323
G2	14.1	0.079	0.883	0.378
G3	14.4	0.080	0.872	0.403
G4	14.4	0.080	0.873	0.404
G5	14.6	0.081	0.868	0.415



(a): *Traditional or "same" pick* **(b):** *"Thin" pick* **(c):** *"Thick" pick*

FIG. 2—*Conceptual comparison of ASTM and stress-energy generated cushion curves.*

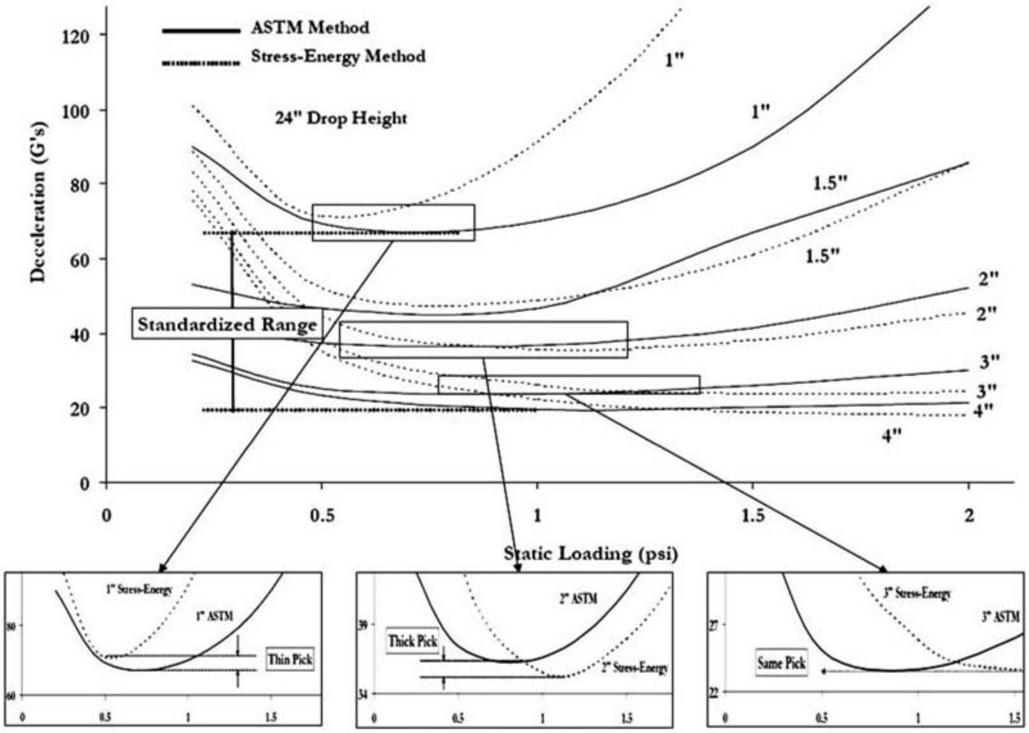


FIG. 3—*Representation of accuracy analysis for 24 in. drop height.*

TABLE 5—*Worst-case percentages of thin and thick pick results for various data sets. (a) First drop (G1) analysis. (b) Average drops 2–5 (G2–5) analysis*

	Number of Energy Levels Used for Calculation											
	11				5				3			
	Thin Pick		Thick Pick		Thin Pick		Thick Pick		Thin Pick		Thick Pick	
Drop Height (in.)	ASTM Range (%)	Absolute Diff (*G*'s)	ASTM range (%)	Absolute Diff (*G*'s)	ASTM range (%)	Absolute Diff (*G*'s)	ASTM range (%)	Absolute Diff (*G*'s)	AST range (%)	Absolute Diff (*G*'s)	ASTM range (%)	Absolute Diff (*G*'s)
					(a) First drop (G1) analysis.							
12	22.0	−5.2	0.00	···	16.9	−3.9	0.00	···	16.5	−3.9	0.00	···
18	14.0	−5.1	4.10	1.5	8.00	−2.9	6.00	2.2	6.10	−2.2	6.90	2.5
24	4.00	−2.0	3.60	1.8	0.20	−0.1	5.00	2.5	0.00	···	6.20	3.1
30	8.00	−4.9	3.00	1.9	2.30	−1.4	4.50	2.7	0.00	···	5.30	3.2
36	15.6	−3.5	14.0	3.2	5.90	−1.3	18.7	4.2	2.80	−0.6	21.0	4.8
42	0.00	···	10.6	3.1	0.00	···	14.8	4.3	0.00	···	16.4	4.8
Avg.	10.6	−4.14	5.88	2.3	5.55	−1.9	8.17	3.2	4.23	−2.2	9.30	3.68
Max	22.0	−5.2	14.0	3.3	16.9	−3.9	18.7	4.3	16.5	−3.9	21.0	4.8
					(b) Average drops 2–5 (G2–5) analysis							
12	27.5	−6.7	0.00	···	21.9	−5.3	0.00	···	22.7	−5.5	0.00	···
18	22.3	−8.1	3.00	1.1	16.6	−6.0	4.40	1.6	18.4	−6.7	3.90	1.4
24	13.0	−6.4	5.00	2.4	7.50	−3.7	6.40	3.1	8.30	−4.1	6.20	3.0
30	15.2	−9.7	3.00	1.6	9.50	−6.1	3.90	2.5	9.30	−5.9	5.30	2.3
36	16.6	−4.2	9.50	2.4	8.50	−2.13	14.9	3.8	11.1	−2.8	14.2	3.6
42	0.00	···	8.60	2.7	0.00	···	12.3	3.9	0.00	···	11.5	3.6
Avg.	15.8	−7.0	4.85	2.0	10.7	−4.6	6.98	3.0	11.6	−5.0	6.57	2.8
Max	27.5	−9.7	9.50	2.7	21.9	−6.1	14.9	3.9	22.7	−6.7	14.2	3.6