Hardness Test Methods Comparison and Correlation with H-Point Measurements

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Abstract

This paper will document the application of two test methods, which have been used for firmness testing, I.R.G.L. (Indentation Residual Gauge Length) and CPF (Constant Penetration Force). In the utilization of these tests over a period of time by those experienced in both polyurethane foam manufacture and seating applications, there was a realization that these firmness tests also had a correlation to H-point (Hip point) positioning.
The data presented will show how these tests not only have the capability of doing this comparison, but show marked improvement over the current firmness measurement in the industry call IFD (Indentation Force Deflection). Further these tests show better repeatability and other correlations to key manufacturing and performance criteria.

Introduction

The Flexible Polyurethane Foam Industry Panel consisting of Original Equipment Manufacturers (OEM), Tier 1's, raw material suppliers and moulded foamers (1), has spent over two years meeting, discussing test methodology, conducting DOE studies, reviewing test data and selecting the most relevant foam properties and test methods for polyurethane seating foams. As part of this Panel, a sub-group from members representing Johnson Controls Inc., Lear Corporation and The Woodbridge Group has worked on foam hardness testing methodologies to ascertain the test with the least variance and how the test correlates with seat complete hip-point (H-point) measurements.

Foam hardness is the key test parameter measured and modified to adjust h-point manikin location on a complete seat assembly. H-point location is unique to each vehicle design and it is used to ensure that the seat package allows an occupant, specifically a driver to see through the windshield correctly without visual interference. The H-point also relates to the occupant ergonomics and it is used as a set-up parameter for federally mandated safety tests. The key objective of this study is to show that a correlation exists between foam hardness testing on molded foam and complete seat H-point measurements.

Background

H-point measurements are time-consuming and expensive to perform, as it requires a complete seat for testing and data analysis. If a particular seat combination does not result in the correct foam cushion and back H-point criteria, new foam parts either softer or harder have to be poured, assembled into the seats and tested. Several iterations may be necessary to achieve the correct H-points. If a less time-consuming test could be used to screen foam seating components prior to incorporation into seat assemblies it would prove to be both useful and cost effective.

With this goal in mind, we have considered three hardness test methods currently used in North America as potential screening tests to predict H-point seating performance. These hardness tests have been initially evaluated to ascertain their extent of testing variance on a number of foam blocks of different thickness and hardnesses and on production cushions. The hardness data has been compared with seat H-point parameters on assemblies made using the same blocks and attempts have been made to correlate these data sets.

Hardness Test Methods

All testing has been performed on parts/blocks cured for several weeks and conditioned at 23±2°C, 50±5% RH. Three methods have been used:

1. Indentation Force Deflection, IFD
    - This test is called for in many standards/specifications with a plethora of variations in procedure including test speed, percentage deflection, delay time between preflexing and testing and zero or up to 60 seconds hold at deflection. We have selected the ASTM D3574-05, Test B1 procedure using test deflections of 25 and 50%. The exact test parameters used can be found in the standard.

2. Indentation Residual Gauge Length, IRGL
    - This test is not used currently by any OEM, but formerly was the hardness test of choice by the Ford Motor Co. until it was superceded by the IFD at 50% deflection test. The IRGL methodology is detailed in ASTM D3574-05 Test B2. Essentially this method applies one or more forces to a foam sample and the residual foam thickness remaining under the indentor after a hold period of 60 seconds is calculated. Usually forces of 111 and 222N are used. Further details can be found in the standard.

      We have used a modified version of this test as we have established that a more rapid test results in values with lower hardness variance; this will be described later.

3. Constant Penetration Force, CPF
    - This method has been introduced relatively recently by Johnston Controls Inc. (2) and is described fully in a Johnson Controls Work Instruction. In summary, this test requires that a sample, after preflexing, is indented for a third time by 75% of its original thickness using an indentation speed of 300mm/min (the same speed as used for preflexing) and the hysteresis loss value is obtained. Also the forces required to cause 15, 20 and 25mm indentation are recorded from the instantaneous readings on the force/deflection curves. These readings, expressed in Newtons, are called the CPF values at these indentations. Specifically the CPF value at 20mm

indentation is termed the foam CPF hardness and a Comfort Index (CPF C. I.) is obtained by dividing the CPF value at 25mm by the CPF value at 15 mm.

Hysteresis Loss, HL

This property is most clearly defined in ASTM D3574-05, Appendix X6. It is the energy lost during compression (loading energy) and recovery (unloading energy) of a foam expressed as a percentage of the loading energy. Usually the sample is indented by 75±5% of its original thickness after one or more precompression. Energy is defined as the area under the force/deflection curve. HL can be measured in all three hardness test methods investigated here, but is particularly useful when used in conjunction with the CPF test.

Methodology

All foams were allowed to recover for a minimum of 24 hours between tests. As indicated earlier, we used the IFD test as detailed in ASTM D3574-05, Test B1 without modification since intensive investigations had shown that changing preload value, test speed, number of prefixes, hold time at force and other variations did not produce results with less variation than the standard method. This held true when duplicate parts were tested.

IRGL testing using different tests parameters resulted in several changes that gave us test values with lower variance. In Table 1, the ASTM standard test parameters appear as “Trial 1” and the parameter set that gave us the lowest test variance as “Trial 2”. Note that preload/ preflex speed/ number of preflexes/ preflex force and test speed have all been increased over the standard conditions. In addition, the preflex-to-dwell interval and the dwell at force times have been eliminated. These changes reduce the total test time from 8.5 to 2 minutes, a significant and desired time savings especially in a plant where a large number of parts must be tested daily.

At a force of 111N, there is no difference in standard deviation and variance between trials 1 and 2. Variance is calculated by dividing the standard deviation by the IRGL average x 100. For the 222N penetration force, there is no difference in the average IRGL values calculated, but the standard deviation and variance are lower for Trial 2. Thus Trial 2 parameters have been selected for continuing investigations. The results are shown in Table 2.

We now tested the same five duplicate parts using the ASTM D3574-05 standard IFD method. The modified (Trial 2) IRGL method and the standard Johnson Controls Inc. CPF method with at least 24 hours separation between each test set. The results are found in Table 3.

From these data sets generated for these parts it can be seen that the IRGL test produces the lowest values for standard deviation and the rates Std Dev/Average x100. Thus the IRGL test may be able to produce less variable results.

Table 1

	Trial 1	**Trial 2**
A – Preload (N)	4.5	10
B – Preflex Speed (mm/min)	200	500
C – No. of Preflexes	2	4
D – Preflex Force (N)	333	700
E – Preflex to Dwell Time (sec)	300	0
F – Test Speed (mm.min)	50	150
G – Penetration Force (N)	111 & 222	111 & 222
H – Dwell at Force (sec)	60	0
Total Test Time	*8.5 mins*	*2 mins*

Table 2

	Specimen Thickness, mm		**Thickness at 111N, mm**		**Thickness at 222N, mm**	
	Trial 1	Trial 2	Trial 1	Trial 2	Trial 1	Trial 2
	80.89	79.08	73.04	73.08	63.36	64.2
	80.52	79.24	73.56	73.26	66.21	65.07
	81.91	79.94	74.03	73.84	64.32	64.38
	80.56	78.38	73.37	72.73	65.77	64.83
	80.27	78.89	72.98	72.9	63.42	65.16
Average	80.82	79.11	73.4	73.16	64.62	64.73
Std. Dev.	0.74	0.57	0.43	0.43	1.32	0.42
Variance	0.55	0.32	0.18	0.18	1.74	0.18

Table 3

A) ASTM D 3574 IFD Method

	Thickness. mm	**25% IFD, N**	**50% IFD, N**	**65% IFD, N**	**R25% IFD, N**
Pad 1	81.0	241.5	428.5	695.3	206.6
Pad 2	80.7	242.9	436.4	716.3	207.9
Pad 3	81.6	232.8	416.8	677.7	199.2
Pad 4	80.0	240.5	430.1	707.2	206.4
Pad 5	80.1	243.4	430.9	705.1	209.1
Average	80.7	240.2	428.5	700.3	205.8
Std. Dev.	0.66	4.30	4.2	14.68	3.87
Ratio (Std Dev/Average *100) =		**1.8**	**1.7**	**2.1**	**1.9**

B) Modified IRGL Test Method (Trial 2)

	Thickness @ 10N, mm	**Thickness @ 111N, mm**	**Thickness @ 222N, mm**
Pad 1	79.56	73.42	65.01
Pad 2	79.65	73.48	65.15
Pad 3	80.26	74.05	64.79
Pad 4	78.73	72.93	64.65
Pad 5	78.68	72.92	65.00
Average	79.38	73.36	64.92
Std. Dev.	0.67	0.47	0.20
Ratio (Std Dev/Average *100) =		**0.64**	**0.31**

C) Johnson Controls Inc. CFP Method

	Thickness, mm	**Load @ 15 mm Pen., N**	**Load @ 20 mm Pen., N**	**Load @ 25 mm Pen., N**	**Hysteresis, %**
Pad 1	81.37	242.2	285.8	328.4	22.15
Pad 2	81.44	241.7	285.8	329.3	22.31
Pad 3	82.14	237.2	278.3	319.8	22.4
Pad 4	80.43	249.1	291.5	334.4	22.31
Pad 5	80.34	253.5	295	337.5	22.51
Average	81.1	244.7	287.3	329.9	22.34
Std. Dev.	0.76	6.49	6.37	6.76	0.13
Ratio (Std Dev/Average *100) =		**2.7**	**2.2**	**2.0**	**0.6**

If we consider one hardness result from each of the three methods, i.e. 25% def. IFD, 222N IRGL and CPF at 20 mm penetration, the data can be analyzed as shown in Table 4.

Where: USL and LSL are Upper and Lower Specification Limit respectively

Cp = (USL –LSL)/(6 x Std. Dev.) = test tolerance

For IFD and CPF the specification range, USL – LSL used in 44N (or ± 22N) and 10mm (± 5mm) for the IRGL range.

Table 4

Hardness Test	**ASTM D3574-25% Def. IFD**	**Modified IRGL @ 222N**	**CPF @ 20mm Penetration**
Average	238.4 N	65.4 mm	290.9 N
Std Dev	4.23 N	0.24 mm	6.75 N
Ratio (Std Dev/Average)	1.8	0.37	2.3
USL – LSL	44 N	10 mm	44 N
6 X Std Dev	25.4 N	1.44	40.5
Cp	1.73	6.94	1.09

Graphically the data in Table 4 can be presented as in Figures 1 and 2:

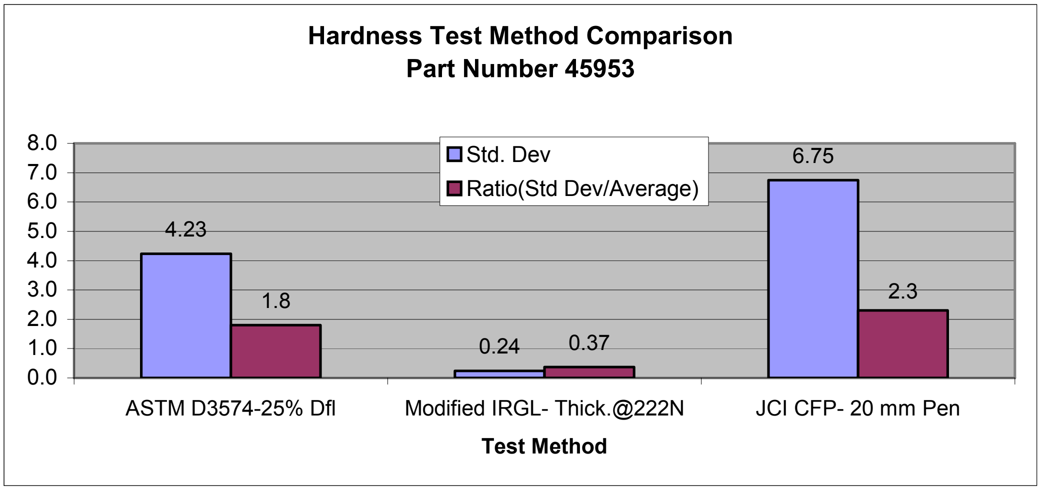

Figure 1

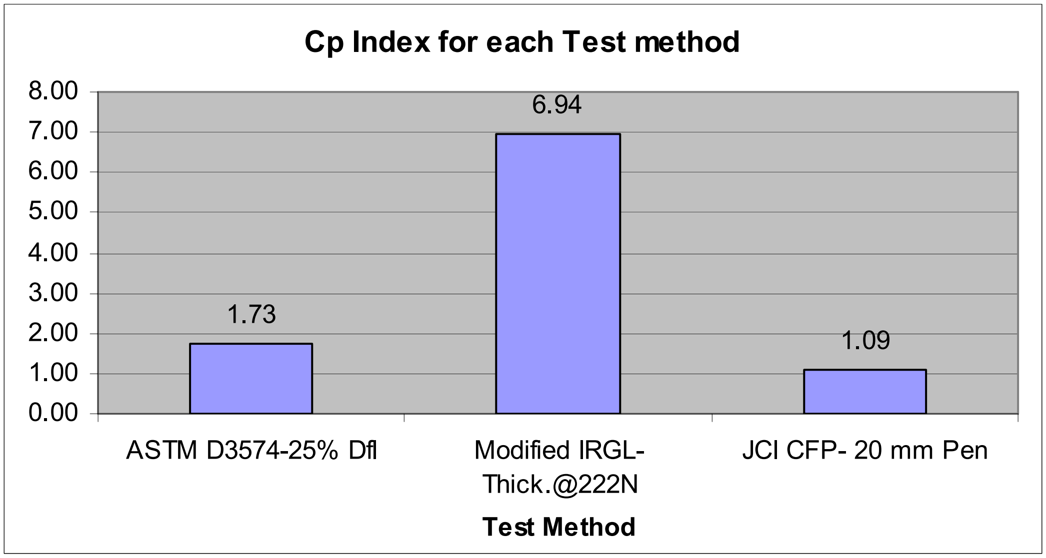

Figure 2

The data for these parts indicates that the test tolerance, Cp as defined above is highest for the IRGL test.

In order to improve our understanding about the IRGL test especially regarding the changes in the parameters as detailed in Table 1, we ran an eight factor/16 trial factorial design on five 75mm thick moulded blocks. We have determined that the only factor that had a significant affect on the IRGL results was the penetration force, i.e. 222 versus 111N. All other parameters were insignificant. This penetration force finding is not surprising and the insignificance (to variation) of the other factors may indicate that IRGL is a robust hardness testing method.

Hardness Comparison of Blocks of Different Thicknesses

Three sets of blocks, 50, 75, and 100mm in thickness have been subjected to the IFD, IRGL and CPF methods. For the 50 and 100mm blocks, three different formulations/hardnesses were evaluated, i.e. ‘low’, ‘medium’ and ‘high’ hardnesses. A summary of the average hardnesses obtained in each test method and their analysis, as detailed earlier, appears in Table 5. Average hardness, at one force level, for the IRGL and CPF methods was tabulated, although the other values, e.g. IRGL at 111 and 222N, were also obtained. IFD was reported at 25 and 50% penetration, since both penetration levels are widely utilized.

Table 5

Part #/Block Thickness	Average Hardness				Standard Deviation				Capability Index (Cp) *			
	IFD @25 % Def., N	IFD @50 % Def., N	IRGL @ 222N, mm	CPF @ 20 mm, N	IFD@ 25% Def., N	IFD@ 50% Def., N	IRGL @ 222N, mm	CPF @ 20 mm, N	IFD@ 25% Def., N	IFD@ 50% Def., N	IRGL @ 222N, mm	CPF @ 20 mm, N
50 mm – Low	107	172	23.04	169	2.41	3.53	0.48	4.24	3.04	2.08	**3.49**	1.73
50 mm – Med.	160	270	32.38	330	3.29	5.56	0.51	8.24	2.23	1.32	**3.27**	0.89
50 mm – High	199	317	37.61	349	2.4	3.02	0.39	1.9	3.05	2.43	**4.31**	3.85
75 mm – High	235	407	61.35	306	2.93	5.58	0.48	4.22	2.5	1.31	**3.47**	1.74
75 mm – Repeat	234	404	61.37	311	2.29	5.70	0.44	3.67	3.2	1.29	**3.78**	2.0
100 mm – Low	124	221	51.48	147	1.50	2.03	0.50	1.79	**4.88**	3.62	3.31	4.1
100 mm – Med.	175	308	67.79	208	1.33	1.33	0.54	1.62	**5.50**	**5.50**	3.09	4.52
100 mm – High	267	481	84.77	327	4.08	6.74	0.69	6.89	1.80	1.09	**2.42**	1.06

* Typical industry tolerances, either those currently in use for IFD and CPF, or in the case of IRGL, the historical value, were used to calculate the capability index for each method. The following values were used (USL – LSL): IFD, 44 N; CPF, 44N; and IRGL, 10 mm.

In Table 5, the Cp values in bold are the highest for each block type. For the three 50mm blocks, the 75mm block and the firmest of the 100mm blocks, the IRGL test gave the highest Cp values. For the soft and medium 100mm blocks Cp values for IFD and CPF were higher than for IRGL. We have tested other blocks made in another facility and found that the IRGL Cp value is usually higher than for the other hardness tests.

In summary, for seat parts and test blocks of various thicknesses and different hardnesses, the modified IRGL test has produced the highest Cp value in 75% of the trials-to-date. The other hardness tests are superior mostly for softer blocks. Thus the modified IRGL hardness test gives the least testing variation for the majority of the materials tested.

Additional Tests

Our next task was to perform H-point (hip point) measurements on these blocks and to attempt to correlate that data with the three types of hardness data reported above.

In addition, we decided to measure some physical properties and attempt to correlate that data with both hardnesses and H-point information. The physical properties we have measured are those that have been established by our Flexible Foam Industry Panel as being both relevant and functional to seating performance. Other necessary properties such as odor, fogging, staining, and flammability compliance have not been included at this time. The properties selected by the Industry Panel are: Die C Tear Strength, Wet Compression Set, Wet CFD change, and Constant Force Pounding. In addition for reference purposes sample core densities have been measured.

Our panel believes that:

a) Die C Tear Strength ASTM D624 is relevant to seat trim/performance
b) Wet Compression Set is the most functional of the compression set properties and can be correlated with durability
c) Wet CFD change is similar to humid aged CFD change, but wet conditioning (50°C, 95%RH) is used as we consider that treatment to be more relevant to automotive seating performance.
d) Constant Force Pounding, ASTM D3574-05, Test I3 is considered a useful screening test for auto-seating and has been shown to correlate with in-vehicle performance (3). The Industry Panel has an active sub-group examining several accelerated durability tests to determine if a superior test is available or can be developed.
e) Hysteresis Loss, ASTM D3574-05, Appendix X6, is a resiliency measurement that correlates to durability and comfort.
f) Core density is a useful reference property.

H-Point Measurement

H-point data has been measured on the three block thicknesses. A generic seat structure, figure 6, was fabricated for performing h-point measurements on the foam test blocks used for hardness testing. The structure consists of a rigid base, an automotive seat back mounted to support the SAE Manikin at a back angle of 25 degrees, and a platform to place the test samples on. The platform is adjustable, by 25mm increments, so the same bite-line could be maintained for the 100, 75, and 50mm thick samples. The base holds the test samples at an angle of 12 degrees to horizontal.

H-point measurements were made per SAE J826, except the manikin legs were not used in this generic format. To stabilize the manikin an extra block of foam was added to the front of the sample platform. A Faro Arm, model S1202, was used to obtain the h-point measurements.

Wooden blocks at approximately 50, 75, and 100 were used to establish baseline h-point heights at the three thickness levels. This allowed for penetration measurements of the foam block samples with the appropriate correction factor to correlate the small differences in the foam block heights. For each block thickness and hardness, three sets of H-point data were obtained:

Table 6

Foam Thickness, mm	Sample	H-Point Penetration (X-Direction) (Average), mm	H-Point Height (Z-Direction) (Average), mm	H-Point Penetration (Z-Direction) (Average), mm	Back Angle, degrees	Cushion Angle, degrees	Thigh Angle, degress
50	E5	4.7	459.4	40.7	21.0	10.9	10.8
50	E6	1.3	458.8	41.2	22.0	11.3	11.6
50	E7	3.2	458.7	42.3	21.5	11.4	11.5
AVERAGE		3.1	**459.0**	41.4	21.5	11.2	11.3
50	B5	4.4	467.5	32.3	21.5	10.9	11.3
05	B6	7.3	468.3	30.4	23.5	11.2	11.5
05	B7	6.6	167.5	30.5	22.5	11.4	11.5
AVERAGE		6.1	**467.8**	31.1	22.5	11.2	11.4
50	D3	2.0	469.9	28.4	21.5	11.0	10.8
50	D1	1.4	467.6	30.7	22.0	11.5	11.7
50	D2	-1.8	466.8	31.2	21.5	11.7	11.3
AVERAGE		0.5	**468.1**	30.1	21.7	11.4	11.3
75	A13	3.6	464.7	33.3	20.5	11.6	11.8
75	A14	9.2	461.5	36.6	21.5	12.1	12.3
75	A6	9.6	463.8	34.4	21.5	11.7	11.9
AVERAGE		7.5	**463.3**	34.7	21.2	11.8	12.0
100	A2	3.5	433.7	62.2	20.0	15.1	15.0
100	A9	5.8	431.0	65.6	20.0	15.3	15.4
100	A5	8.8	431.8	64.5	20.0	14.7	14.9
AVERAGE		6.0	**432.2**	64.1	20.0	15.0	15.1
100	C6	-0.8	445.6	51.9	20.5	14.5	14.4
100	C3	2.5	449.1	48.7	21.5	13.3	13.4
100	C7	-2.1	446.9	50.9	20.5	13.5	13.6
AVERAGE		-0.1	**447.2**	50.5	20.8	13.8	13.8
100	D1	2.7	464.9	33.3	23.0	11.4	11.6
100	D2	1.8	464.6	34.0	22.0	11.3	11.7
100	D4	-1.6	465.2	33.3	22.0	11.5	11.5
AVERAGE		1.0	**464.9**	33.5	22.3	11.4	11.6

The average H-point height (z-direction) has been compared with the equivalent IFD, IRGL, and CPF values in Table 7:

Table 7

Foam Thickness, mm	Foam Hardness Type	25% IFD, N	222N IRGL, mm	CPF @ 20mm, N	H-point height (z), mm
50	soft	106	23	153	459
50	medium	161	33	270	468
50	hard	201	38	301	468
75	-	235	62	273	463
100	soft	124	52	122	432
100	medium	175	68	171	447
100	hard	265	84	260	465

In Fig. 3(a), (b), and (c) the H_z-points are plotted versus the IFD, IRGL, and CPF values tabulated above.

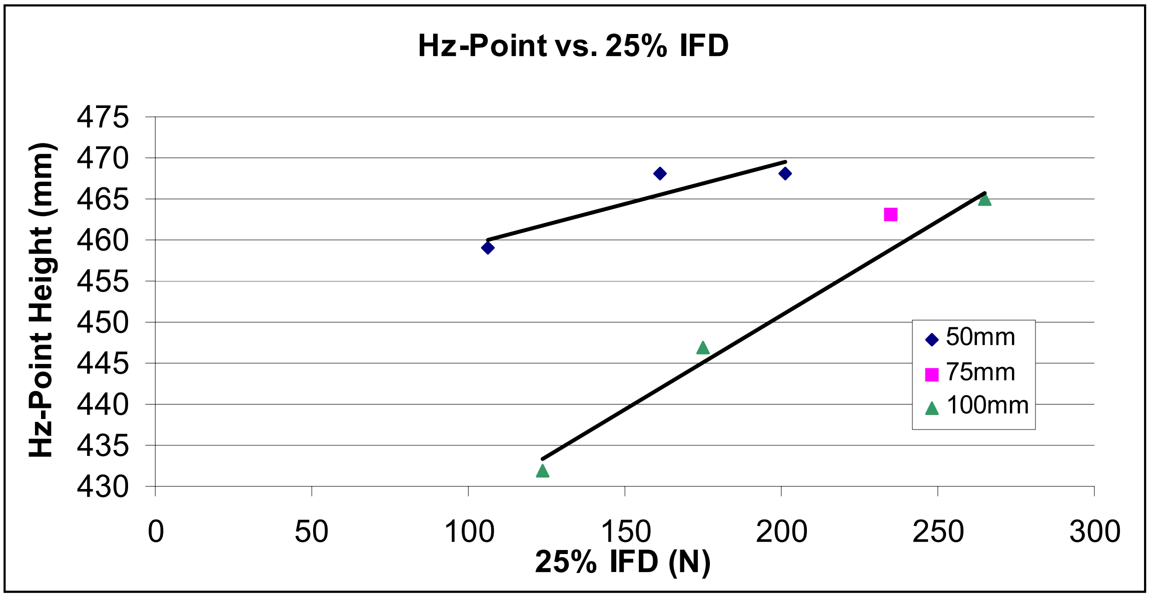

Figure 3a

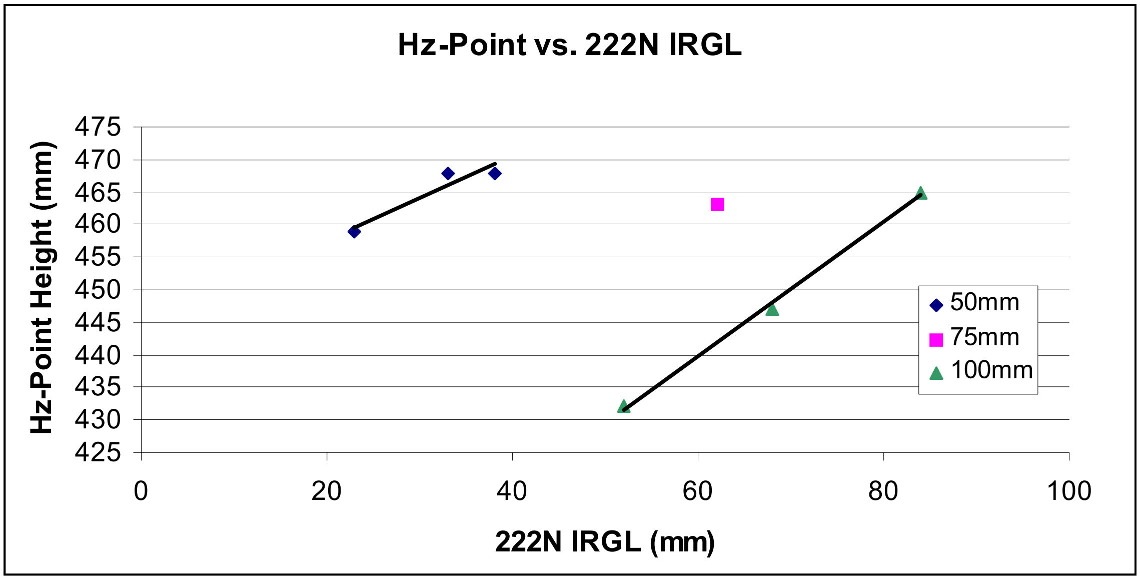

Figure 3b

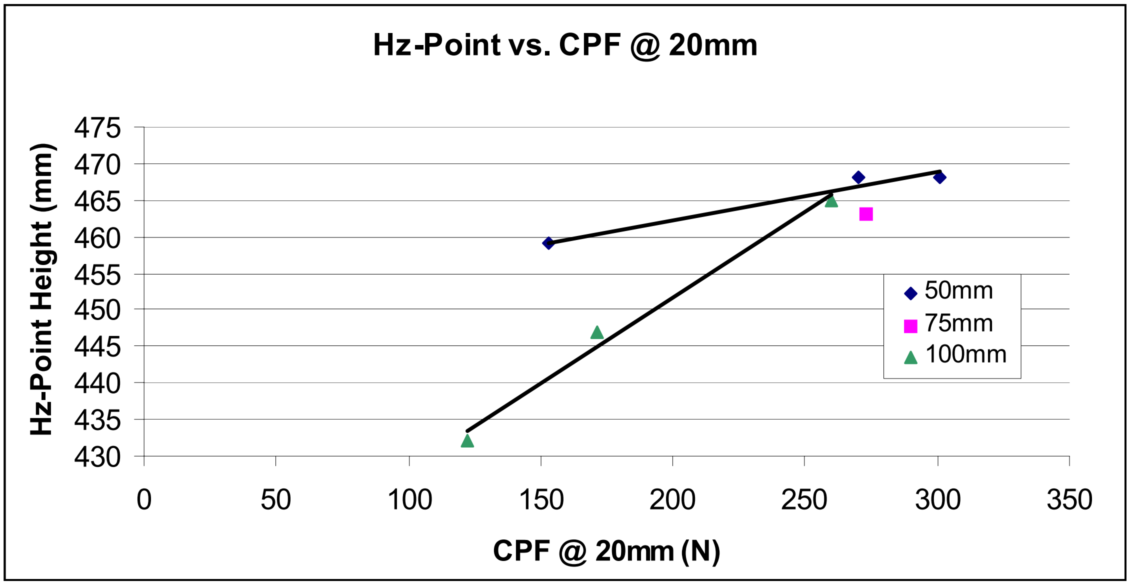

Figure 3c

For each block thickness the H-point value versus foam hardness is linear. The IFD and IRGL relationships for the different foam thicknesses are quite separate, but the CPF correlations appear to intersect at higher hardness, e.g. at 230N. There is not a "universal" relationship between H-point and any of these hardness measurements that is independent of block thickness.

If the same data is plotted versus block thickness, Fig.4, the following is observed:

a) H_z-points do not change or decrease slightly with increasing block thickness,
b) IFD values increase with thickness for all foam grades,
c) IRGL values increase with thickness for all foam grades,
d) CPF values decrease with thickness for all foam grades.

Thus only the CPF data appears to show the same trend as the H_z-point data.

However, if we consider the IRGL penetration values, i.e. the distance the indentor moves into the foam test piece when a force is applied, we obtain the values listed in Table 8.

For example, if a force of 222N is applied to a 100mm thick block the IRGL value is 51.5mm. Thus the IRGL penetration value is 48.5mm. We have plotted the H_z-point values, also shown in Table 8, against the penetration values for each force (111, 222, and 333N) in Fig.5. For each force value we obtain a linear correlation with H_z-point for the three block thicknesses. The correlation coefficients are shown in Table 9.

Thus our data indicates a good correlation between IPD (where IPD = Indentation Penetration Deflection) and seat H-point in the z-direction, i.e. vertical direction. If these relationships hold true for other foams and parts, the correlation can be used to predict H_z-points from IPD determinations.

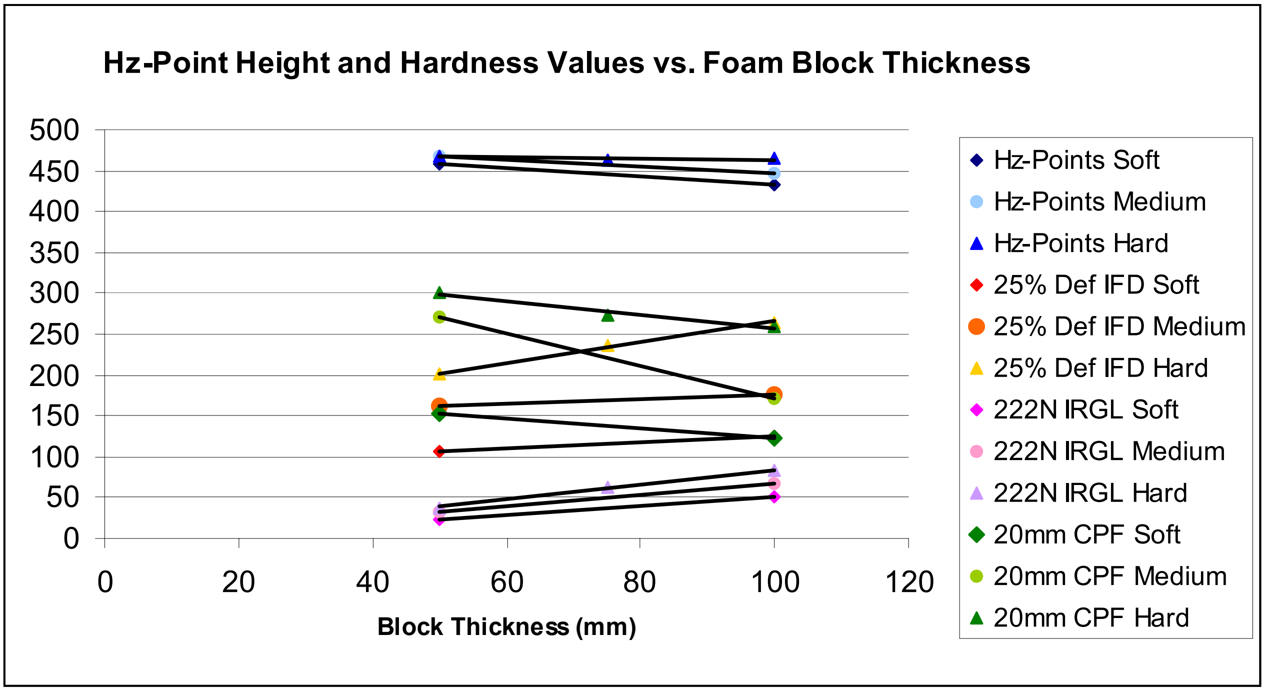

Figure 4

Table 8: Correlation Between IRGL and H_z-Point

Block Thickness (mm)	IRGL (mm)			IRGL Penetration (mm)			H_z-Point (mm)
	111N	222N	333N	111N	222N	333N	
50	40.2	23.0	17.28	10	27.0	32.8	459
50	45.6	32.4	24.06	4.4	17.4	25.1	468
50	47.2	37.6	26.92	2.8	12.4	23.1	468
75	72.1	61.4	-	3	13.6	-	463
100	78.2	51.5	37.9	21.8	48.5	62.1	432
100	90.6	67.8	51.0	9.4	32.2	49.0	447
100	95.0	84.8	70.2	5.0	15.2	29.8	465

Table 9

Force	R^2
111N	0.8851
222N	0.9368
333N	0.9888

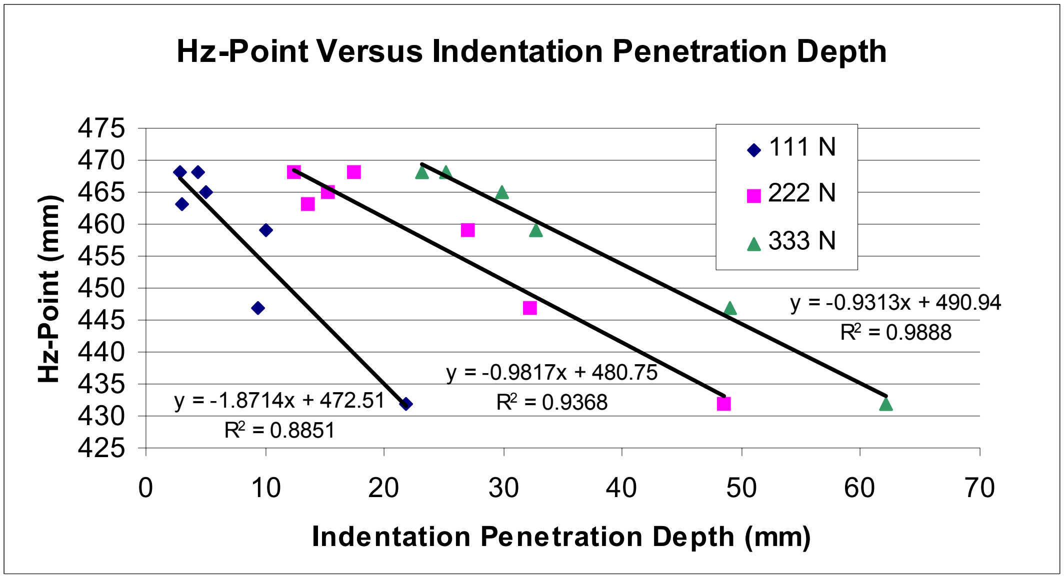

Figure 5

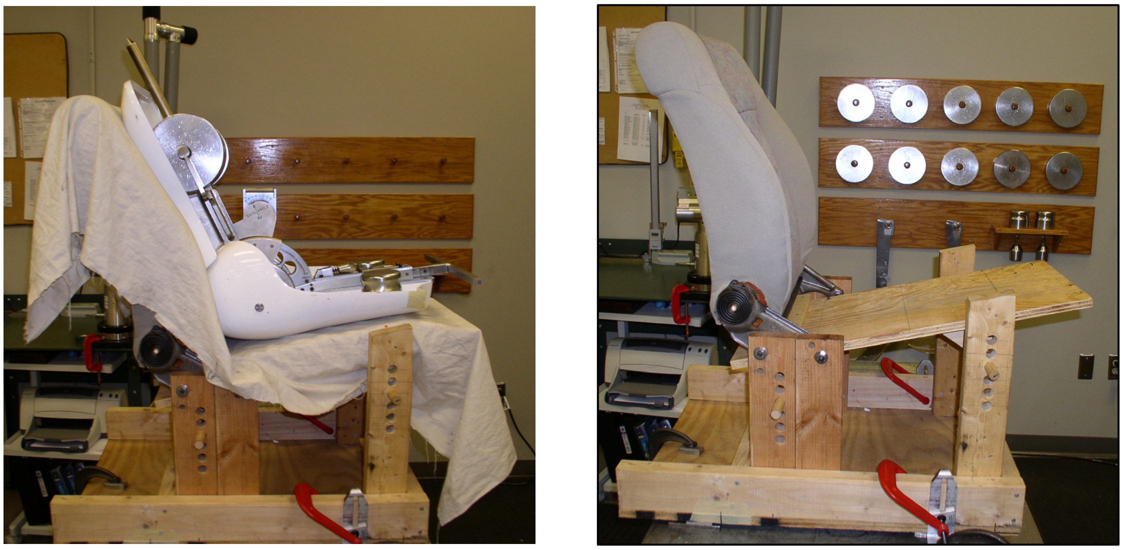

Figure 6

Physical Properties

The block physical properties are found in Table 10. The properties listed are those that the Flexible Moulded Foam Industry Panel consider to be functional properties, i.e. these properties correlate with seat performance.

50% Wet CFD change is the hardness change of a 50x50x25mm block, without skin, tested before and after being subjected to an environmental treatment of 50^{o}C/95% RH for 22 hours, the same conditions used for wet compression set ageing (see ASTM D3574-05, Test L). Hardness changes after 30 minutes and 24 hours recovery have been determined. Similarly, thickness and IFD hardness change after Constant Force Pounding (see ASTM D3574-05, Test I3), after 60 minutes and 24 hours recovery, are tabulated.

All die C tear strengths are well above our Panel's 450N minimum acceptable value. Wet Set values vary between a low of 9% and a high of 27%. Note that the higher density foams have lower wet sets. Wet CFD change does not correlate with core density and this most probably indicates that this change is governed by foam composition, e.g. urea/polymer solids content/isocyanate index.

Constant Force Pounding IFD changes vary between a high of 26% for a 32 kg/m^3 density foam and 12% for 46 kg/m^3 foam. However, there is not a linear correlation between hardness change and foam core density. For instance 32 kg/m^3 foams exhibit hardness changes as wide apart as 15 and 26%. Thus durability changes are not directly correlatable with foam density although in general higher density foams do exhibit lower hardness losses. Increasing the recovery time to 24 hours allows both thickness and hardness to decrease. Hardness losses decrease by 6 to 9% after 24 hours ageing and further decreases have been recorded after even longer ageing times leaving only a small amount of 'permanent' hardness loss.

One of the reasons our Panel selected Wet Compression Set as an important functional property was that we had demonstrated a good correlation between Wet Set and pounding hardness loss. This is illustrated for the foams tested in this investigation in Fig. 7.

Table 10

1. Block Thickness (mm)	50	50	50	75	100	100	100
2. Die C Tear Strength (N/m)	644	850	787	923	668	778	787
3. 50% Def. Wet Set (%)	9	27	12	13	19	15	12
4. 50% Def. Wet CFD Change (%)							
a) 30 minutes	6.3	6.1	5.1	16.3	16.9	30.0	5.1
b) 24 hours	1.5	2.9	2.0	2.7	2.0	10.1	2.0
5. Constant Force Pounding							
a) 30 mins: Thickness Change (%)	2	5	2	2	2	2	2
IFD Change (%)	12	26	14	13	15	18	14
b) 24 hrs: Thickness Change (%)	1	3	1	1	1	1	1
IFD Change (%)	6	17	8	8	7	10	8
6. Core Density	46	32	44	44	32	38	44
7. Hysteresis Loss* (%)	18-19	32-34	23-24	23-24	23-24	23-24	25-26

**Obtained from the IFD and CPF Loading/Unloading Hardness Curves*

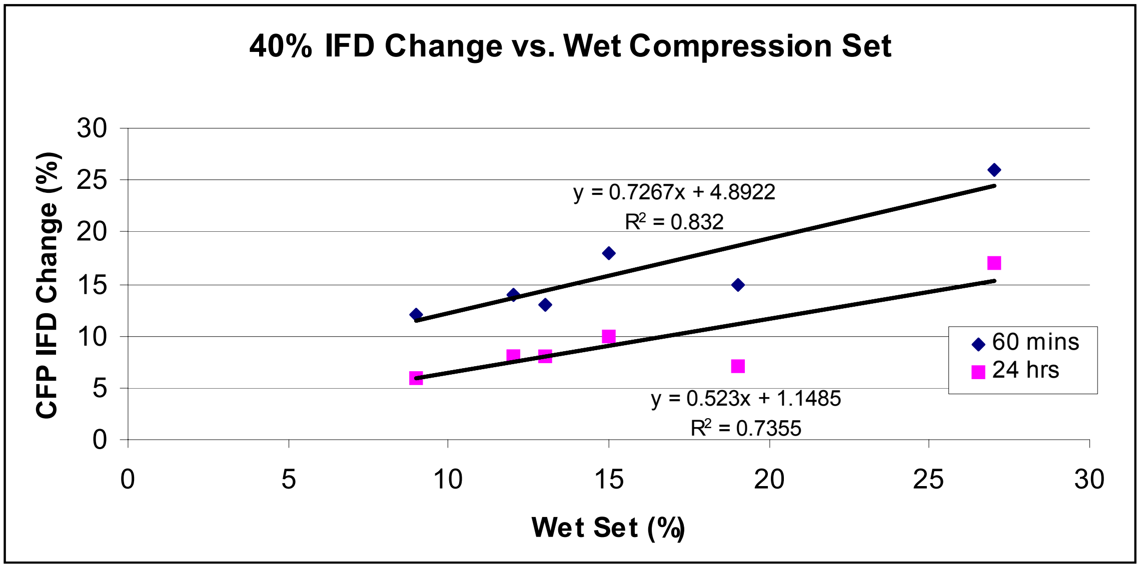

Figure 7

Both sets of IFD changes plotted against Wet Set values exhibit linear correlations. Thus wet set determinations, which are inexpensive and many materials can be tested simultaneously, will give a good indication how foam will perform in the Constant Force Pounding (CFP) test. In addition, it has been shown previously that there is a fairly food correlation between CFP test results and in-vehicle seat performance (3).

Hysteresis Loss values can be obtained from any of the hardness tests evaluated here. The only difference we have found in these values is caused by the use of different crosshead speeds. For instance an ASTM D3574-05 recommended speed of 50mm/min will produce a slightly lower (1-2%) hysteresis loss than if the hardness test is performed at 300mm/min (CPF test). Our data in Table 9 indicates moderate correlation between hysteresis loss values and both Wet Sets and CFP IFD changes, i.e. hysteresis losses increase with wet compression set or CFP IFD change.

Conclusions

1. A modified IRGL test produces hardness values with the least testing variance (compared with IFD or CPF testing).
2. H-points in the z(vertical) direction have been correlated with penetration distances in the IRGL test.
3. IPD values can be used to predict z-direction H-point seating values.
4. There is good correlation between Wet Compression Sets and % hardness loss after Constant Force Pounding.
5. Hysteresis Losses obtained from hardness determinations correlate moderately well with Wet Set and CFP IFD changes.
6. The foam physical properties selected by the Flexible Moulded Foam Industry Panel are functionally-related to foam seat performance and are recommended as both viable and sufficient to predict seating foam performance.

Future Investigations

Our immediate goal is to establish if the H_z-point/IPD correlation is valid for other foam block formulations and densities. We suggest that the H_z-point/IPD relationship, if proven over a range of chemistries/densities, will be a useful tool for seat design/specifications. Therefore, we will investigate this correlation for actual automotive seat cushions of different thickness, geometry and formulations. Assuming an acceptable relationship is established, the information can be used by seat design engineers to predict part hardness from the H_z-point design target or vice-versa.

The correlation established in this report will only apply to dead pan seating construction. Further studies will be required to establish any correlation between IPD and H_z-point for suspension-mounted seats.

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Biographies

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Ron Blair has received his degrees in Glasgow Scotland. He continued his studies at the University of British Columbia before joining Royal Dutch Shell Plastics Laboratory in Holland. During his six years with Shell, he worked in various functions including fundamental research, plastics testing and latterly, polyurethanes. In 1976 he joined Monsanto Canada, which became Woodbridge Foam Corporation in 1978. He has held various processing and chemistry positions and currently manages the Woodbridge P3T Laboratory, Woodbridge Ontario, Canada.

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