A Future FOR THE Sport

FOOTPRINT RESEARCH REPORT

OCTOBER 2023

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Contents

NOTE: Additional acknowledgements in blue on pages 3 and 12 added in November 2023 update.

PURPOSE

To investigate the measurability of bowling ball footprint and its correlation to ball performance.

SUMMARY

USBC has published a new standard operating procedure (SOP) to repeatably measure the footprint diameter of a bowling ball.
Using this SOP, USBC measured a wide range of urethane balls that varied in produced hardness. USBC also measured urethane balls after use tracking not only on hardness changes, but also footprint size changes.

Key findings:

- A repeatable SOP was prototyped and utilized to measure footprint diameters of bowling balls.
- A bowling ball's production hardness and footprint size are strongly correlated to one another.
- Balls that measure softer through use do not exhibit a strong correlation to change in footprint.
- This study reinforces that urethane bowling balls dropping in hardness measurements through use does not impact ball performance on the lane.

DISCUSSION

To further the research into the effects of ball hardness and performance on the lane, USBC wanted to better understand how footprint or contact area may impact ball performance. We set out to develop an SOP that can accurately measure the contact between balls and the ground.

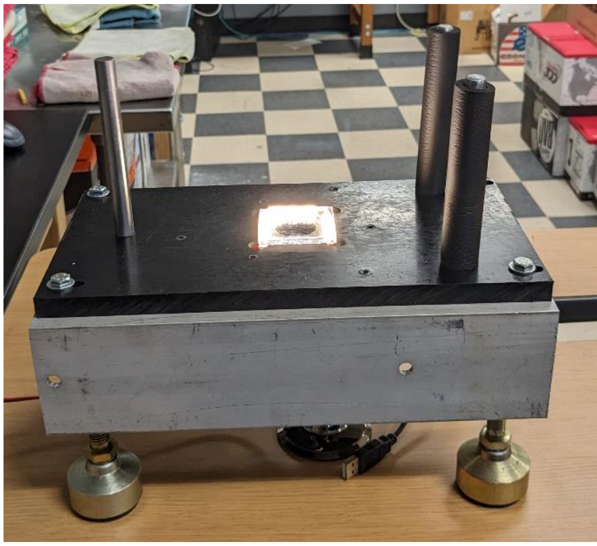
Different sources make different arguments regarding the effects of contact area size on the coefficient of friction. Most physics textbooks argue that the coefficient of friction is unaffected by the size of the contact area. The premise that they are not related is based on the observation that the percentage of the contact area that is actually touching the other surface is negligible. That is to say, if you zoomed in extremely close to the interface between two objects, the areas where the molecules of one material are actually contacting the molecules of the other are few and far between. Conversely, if you interview an expert on racing tires about the coefficients of friction of treadless racing tires, and traditional treaded street tires, you will find that the contact area is of great importance. The key difference is that the rubber of tires is deformable under the weight of the vehicle. Once one of the materials involved is deformed, the argument that true contact area is a negligible percentage of the contact surface area is no longer valid and contact area becomes an important factor.

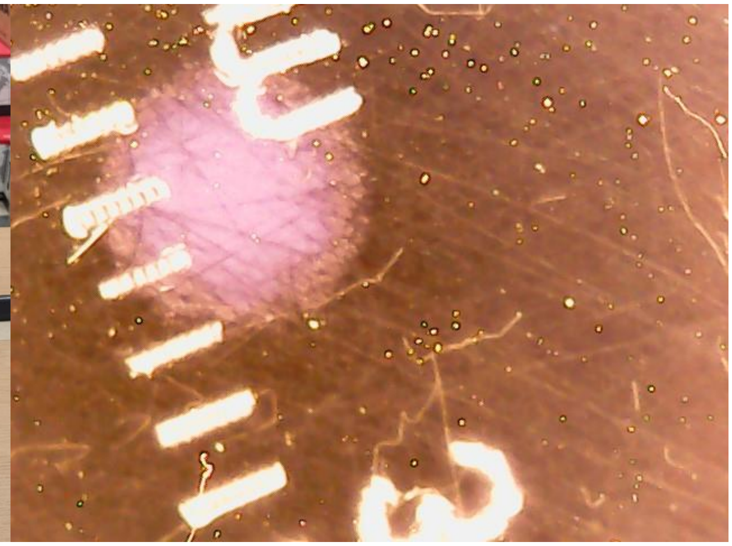
USBC has developed an SOP that involves a structure that holds a bowling ball in place atop a piece of borosilicate glass. We then view the contact area between the ball and the glass from below using a USB microscope camera.

USBC credits Magnum Bowling Products for introducing us to the concept and means for measuring a bowling ball's footprint size using a similar fixture with an etched borosilicate glass and a USB digital microscope as tools for this measurement. Magnum shared its documented studies and designs in this area with USBC which was also featured on the Bowling Explained podcast in March of 2021.

The following is a picture of the structure design for USBC's SOP, and an image of an example contact area.

RESEARCH





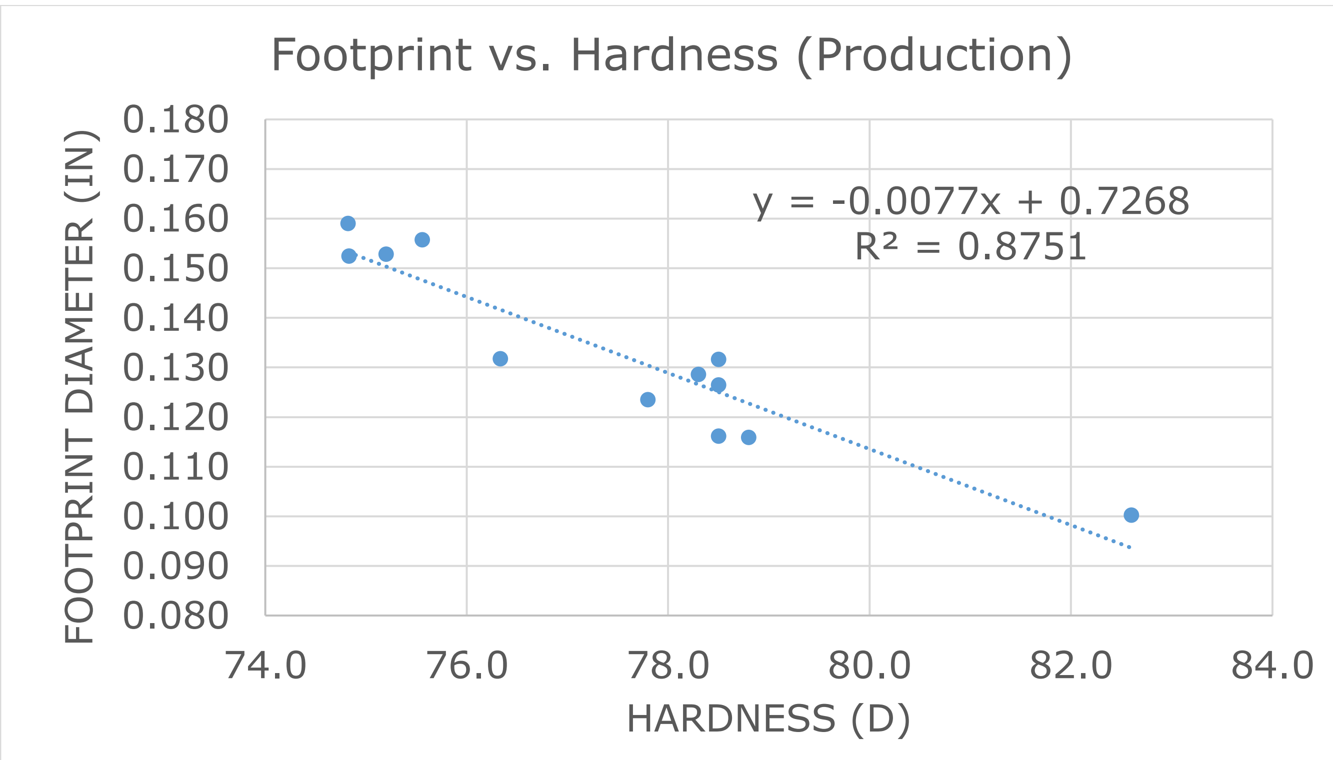
On the piece of glass, we have laser engraved a millimeter measurement scale. Once an image of the footprint has been saved, we can transfer it into our Keyence VH-X microscope to use its image analysis tools to measure the scale of the picture and the diameter of the footprint. When evaluating a new measurement system, our first step is to perform a gauge R&R, a series of 10 balls was measured twice by the operator conducting the research to evaluate the repeatability. Each sample was measured in 10 locations around the ball and the results were averaged. The process was performed twice per sample and the resulting data is as follows.

Sample	Set	Footprint (mm)	Sample Average (mm)	Sample Average (in)
Sample 1	1	3.39		
Sample 1	2	3.39	3.39	0.133
Sample 2	1	3.47		
Sample 2	2	3.37	3.42	0.135
Sample 3	1	3.37		
Sample 3	2	3.32	3.34	0.132
Sample 4	1	3.50		
Sample 4	2	3.45	3.47	0.137
Sample 5	1	3.44		
Sample 5	2	3.43	3.44	0.135
Sample 6	1	2.55		
Sample 6	2	2.54	2.55	0.100
Sample 7	1	4.15		
Sample 7	2	4.10	4.12	0.162
Sample 8	1	3.97		
Sample 8	2	3.93	3.95	0.156
Sample 9	1	3.37		
Sample 9	2	3.28	3.33	0.131
Sample 10	1	3.59		
Sample 10	2	3.55	3.57	0.141

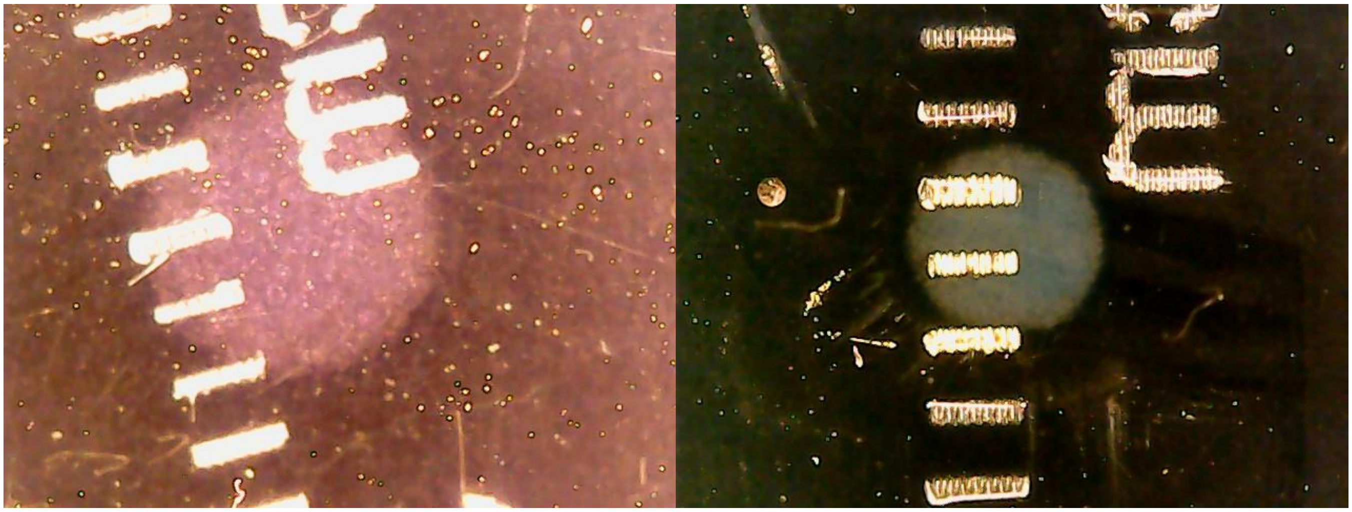
Gauge Stats	(mm)	(in)
Range:	1.577	0.062
Total Gauge	0.038	0.001
Total Variation	0.419	0.016
Distinct Categories	15.546	15.546
Gauge Discrimination	0.101	0.004

The result of the gauge repeatability study showed us that our measurement process is accurate to 0.1 mm or 0.004 inches. What that means is our measurement uncertainty is 0.004” and when we observe differences larger than our gauge uncertainty, we can be confident we are observing true differences. The natural differences in the 10 parts selected for the study ranged 0.062”, illustrating that our measurement uncertainty is much smaller than the observed sample-to-sample differences.

Based in physics, there are two main properties that would dictate the size of the contact area of a bowling ball: the weight of the ball and the malleability of the coverstock material. To examine these relationships, we measured many urethane samples that ranged different manufactured hardness values. The results showed a strong trend between hardness and footprint measurements as expected.



Here we see a trend of -0.0077” in footprint diameter for each point of hardness, with an R-sq value of 0.8751. That means for each point of hardness a urethane ball is made softer, the footprint grows about 0.008” or, about the width of four human hairs (approx. 0.002” each). This trend is what we see with changes in manufactured hardness.

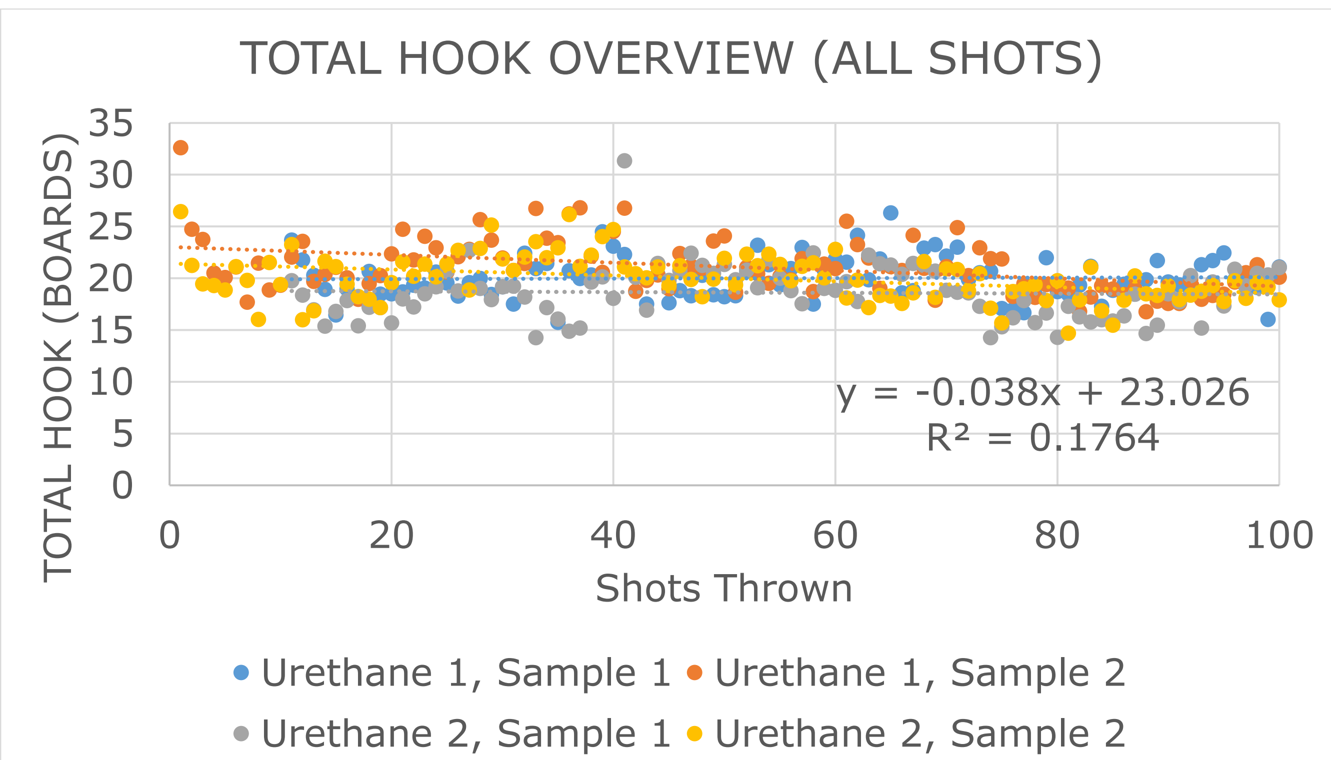


74.8 Hardness Urethane
Footprint: 0.159″

82.6 Hardness Urethane
Footprint: 0.100″

During last year's hardness research, which we reported on at the end of 2022, we observed that the on-lane performance of balls that were manufactured at different hardness values was different. More specifically, balls produced at lower hardness hooked earlier and more overall than their harder counterparts. However, we observed no meaningful difference in the performance of equipment that softened with use. With the addition of this new measurement system, we recreated the testing from last year but this time incorporated footprint size with use as well as hardness with use. The following shows our results:

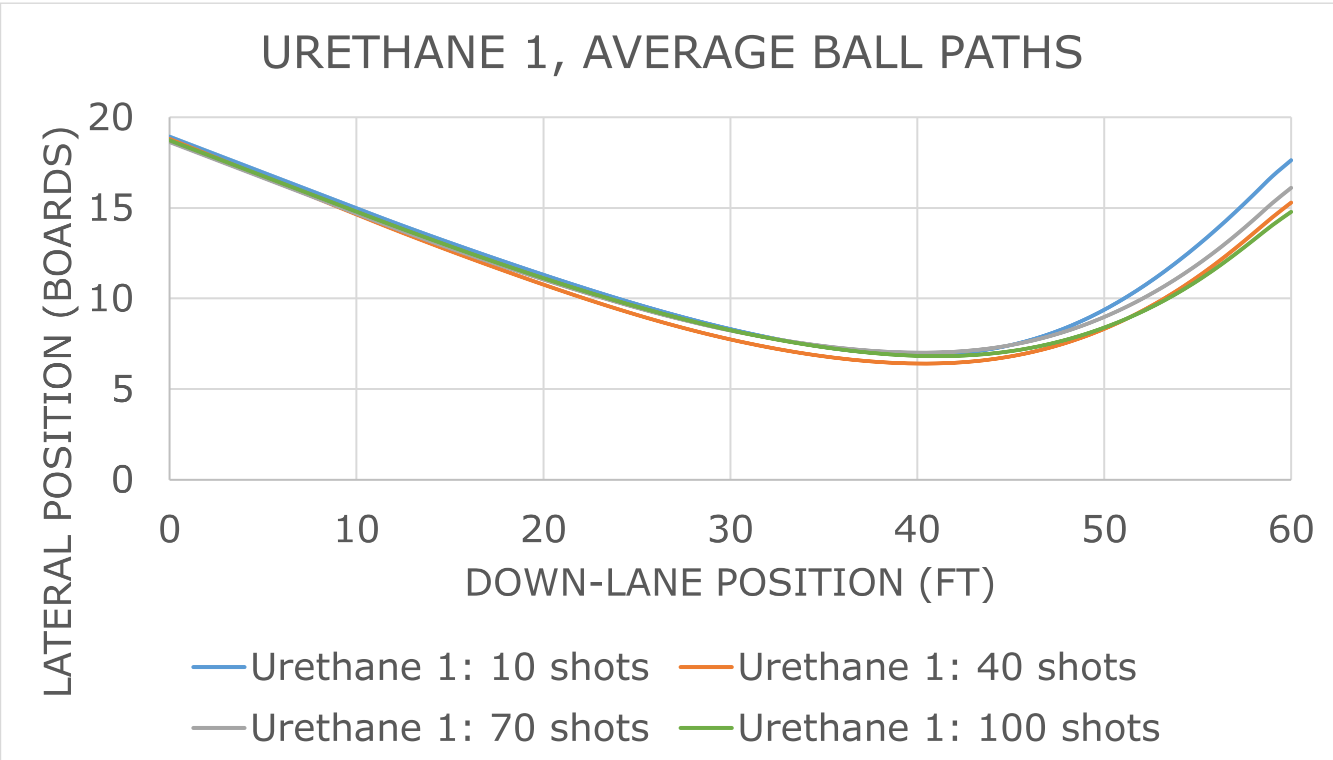
Tracking total hook versus shot count for each sample thrown we see no meaningful change in overall hook performance.

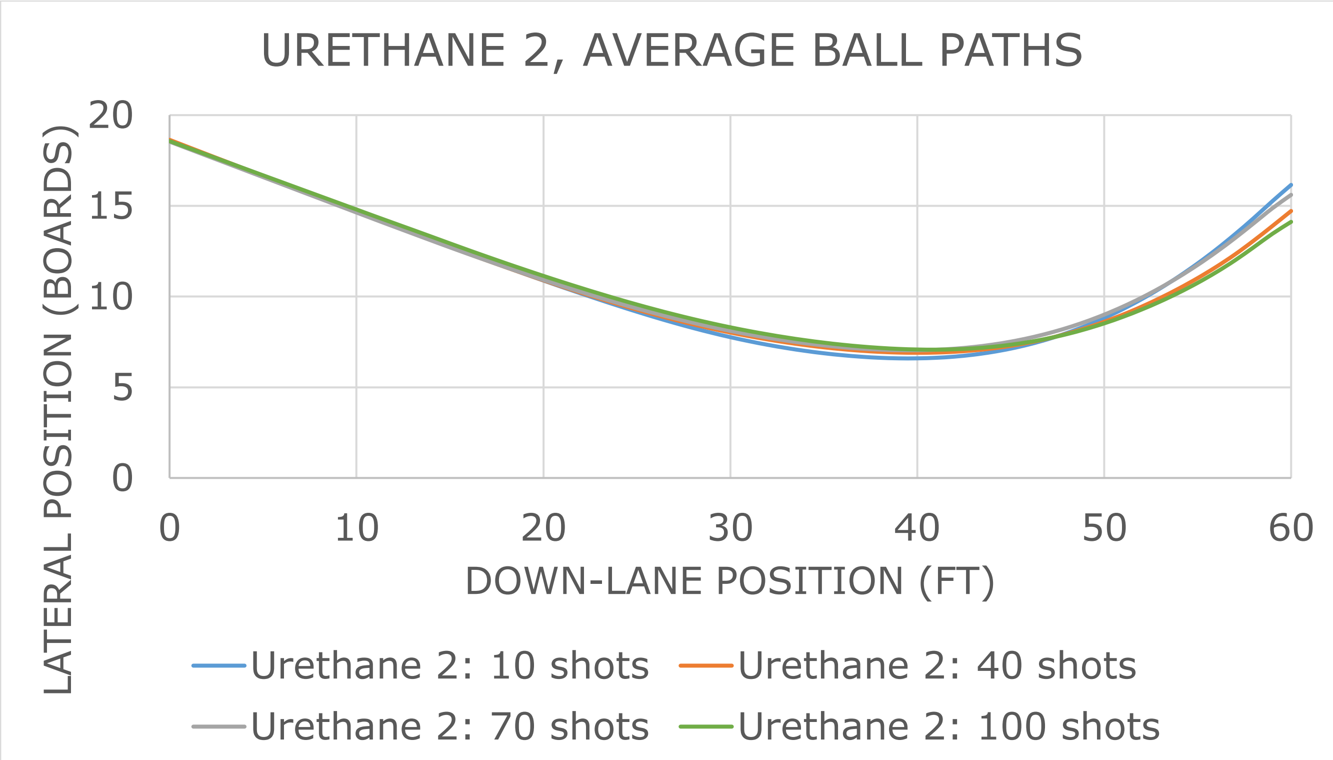


The shots that hook the most are the first shots with a clean surface. As the urethane balls collect some oil on their surfaces, their performance calms down and stabilizes. This is nothing new, and anyone who resurfaces their urethane equipment regularly, knows to expect the first few shots with a fresh surface to hook much more than the ball typically does.

The shots were thrown by performing a 10-shot baseline, and then a series of three tests of 30 shots for a total of 100 shots with each sample. After each test, the balls were cleaned with IPA, and allowed to rest overnight in the lab prior to being tested for hardness and footprint the next day.

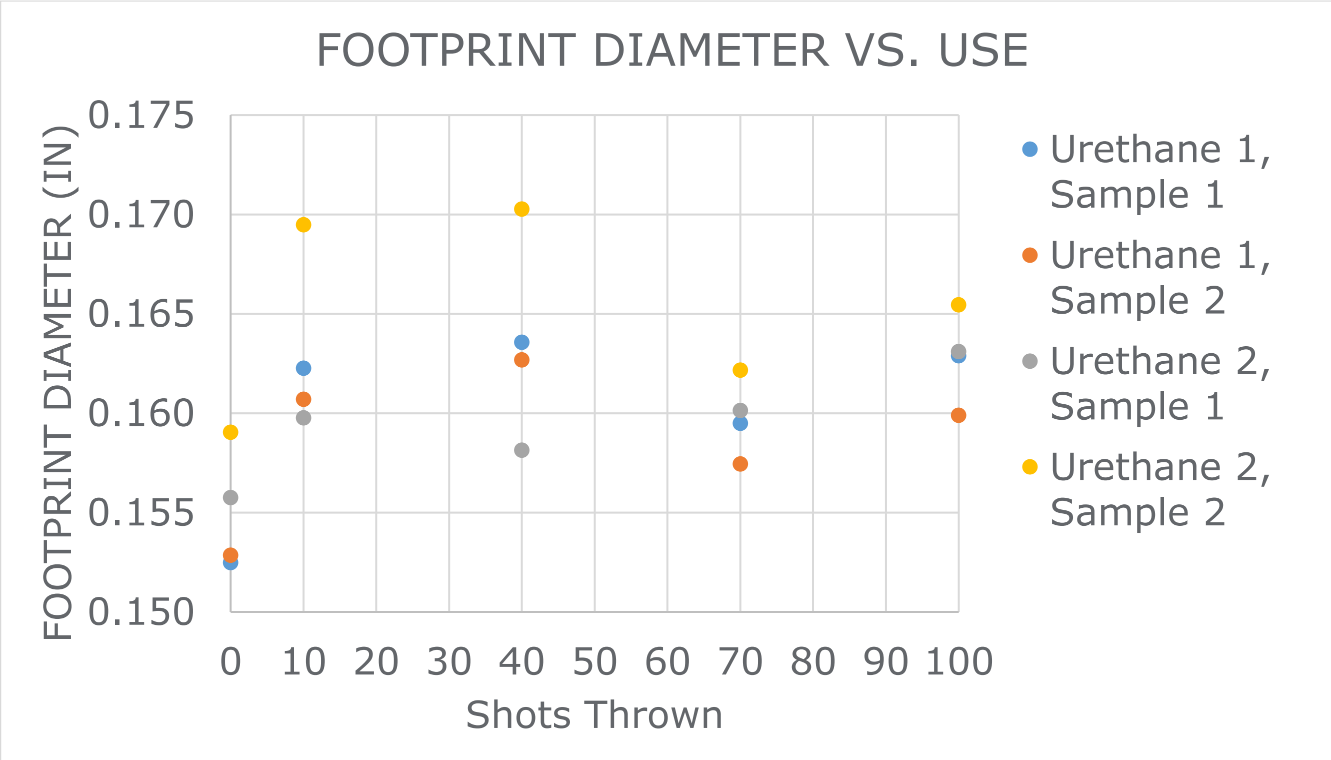
Reviewing the average ball paths for each test thrown by each urethane type shows the same results; the very first test (the 10-shot baseline) hooked a bit more than the rest. The least amount of hook was always the final test, shots 71 through 100.



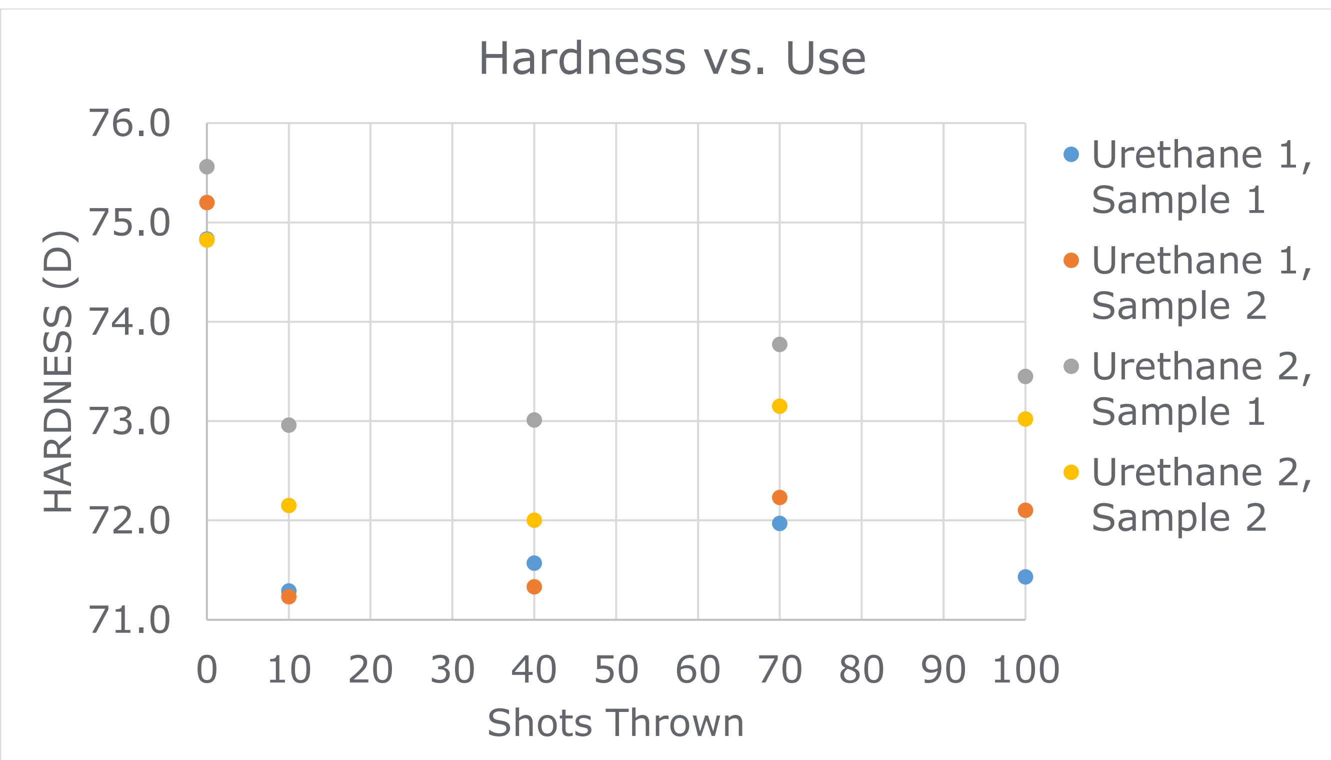


Reviewing the data collected on hardness and footprint we see that the bulk of the changes occurred in the first 10 shots, and then the results tend to stabilize.

Ball	Shots	Footprint Diameter (in)	Hardness (D)
Urethane 1, Sample 1	0	0.152	74.8
Urethane 1, Sample 1	10	0.162	71.3
Urethane 1, Sample 1	40	0.164	71.6
Urethane 1, Sample 1	70	0.160	72.0
Urethane 1, Sample 1	100	0.163	71.4
Urethane 1, Sample 2	0	0.153	75.2
Urethane 1, Sample 2	10	0.161	71.2
Urethane 1, Sample 2	40	0.163	71.3
Urethane 1, Sample 2	70	0.157	72.2
Urethane 1, Sample 2	100	0.160	72.1
Urethane 2, Sample 1	0	0.156	75.6
Urethane 2, Sample 1	10	0.160	73.0
Urethane 2, Sample 1	40	0.158	73.0
Urethane 2, Sample 1	70	0.160	73.8
Urethane 2, Sample 1	100	0.163	73.5
Urethane 2, Sample 2	0	0.159	74.8
Urethane 2, Sample 2	10	0.169	72.2
Urethane 2, Sample 2	40	0.170	72.0
Urethane 2, Sample 2	70	0.162	73.2
Urethane 2, Sample 2	100	0.165	73.0

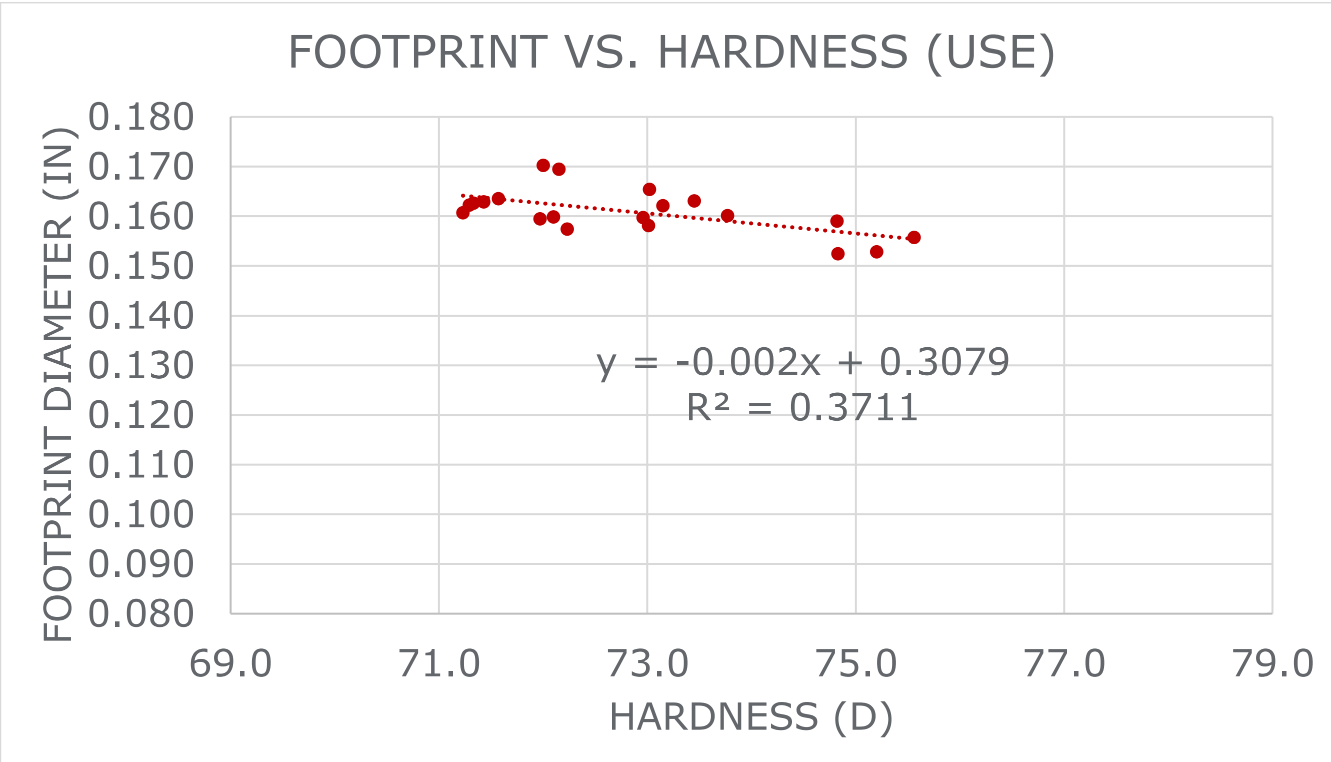


The average footprint diameter before use for the Urethane 1 samples was 0.153”, after 10 shots the measurement grew to 0.161” a change of 0.008”. For the Urethane 2 samples, their footprint diameter was at 0.157” before use and grew to 0.165” an increase of 0.008”.

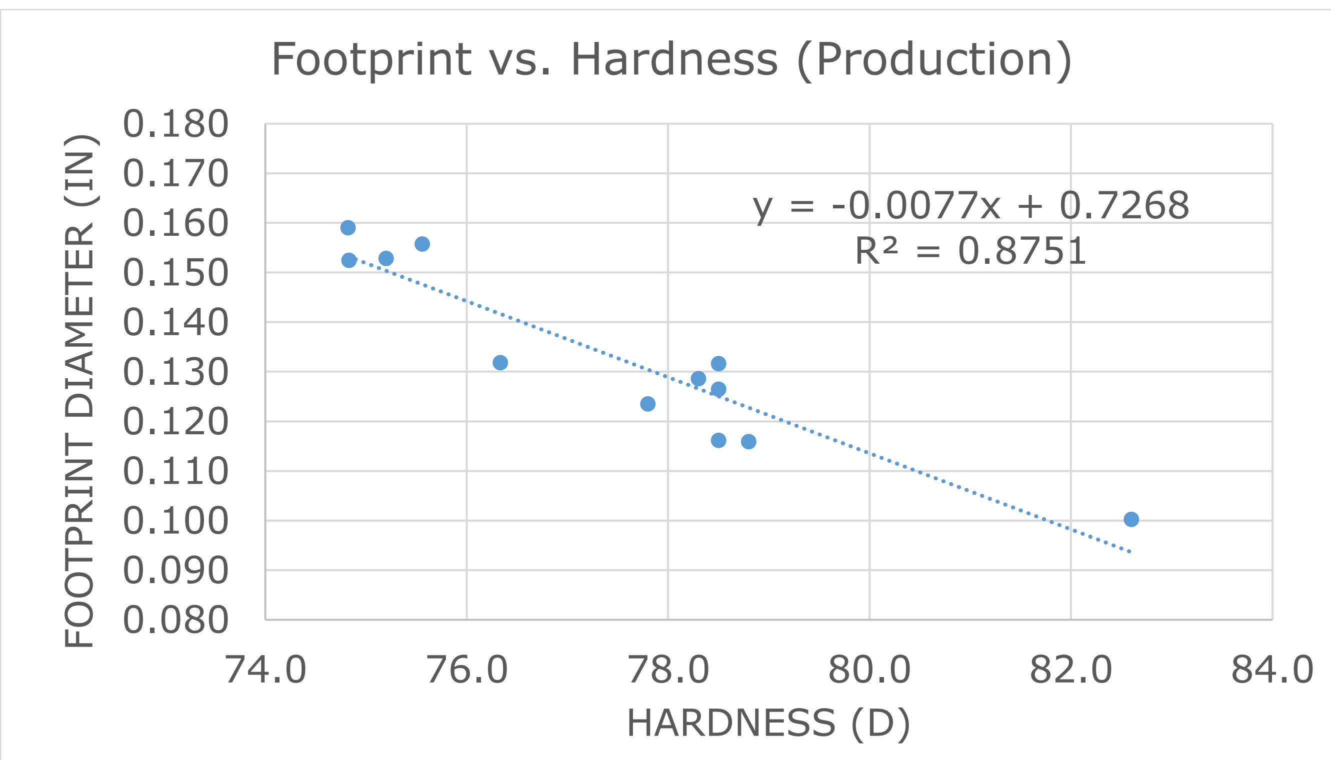


The hardness results show the Urethane 1 samples averaged 75.0 D before use and the Urethane 2 samples averaged 75.2 D before use. After 10 shots, the Urethane 1 samples experienced a 3.7 D drop to 71.3 D and the Urethane 2 samples experienced a 2.6 D drop to 72.6 D.

If we model the relationship between hardness changes with use, and footprint changes with use, we get the following trend.



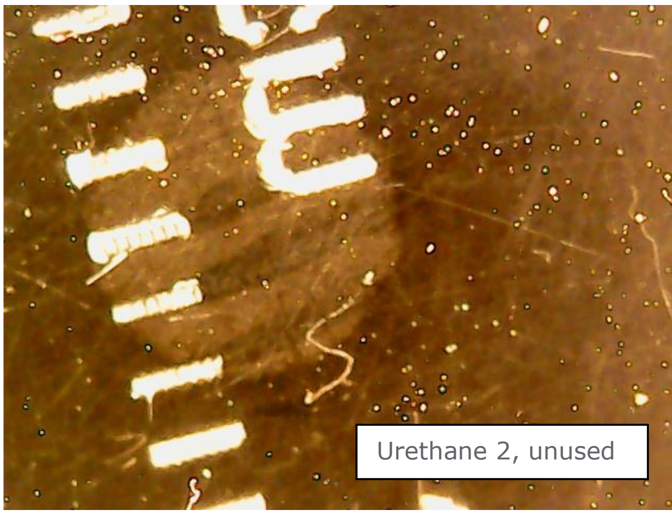
This trend is a stark comparison with the previous trend observed with produced hardness and footprint diameter. The slope is nearly a quarter of the original trend, the R-squared value representing the strength of the trend is less than half what we saw before.

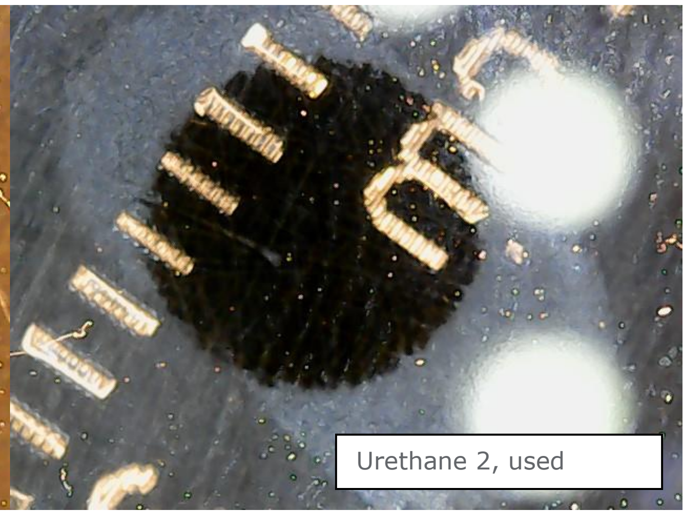


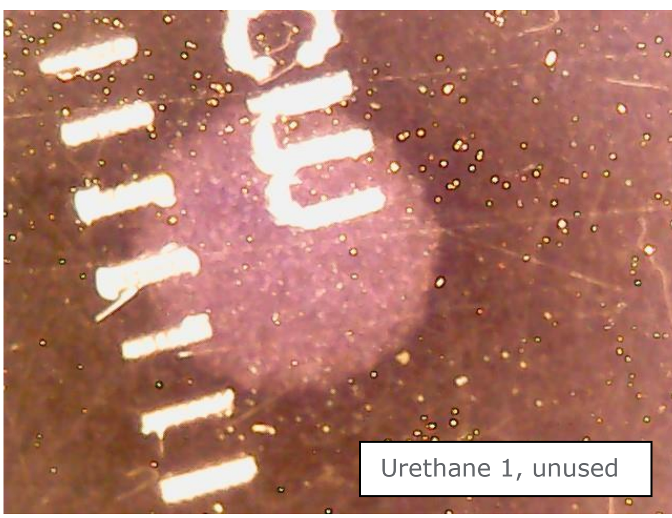
Let’s take a moment to review the key points we have observed so far:

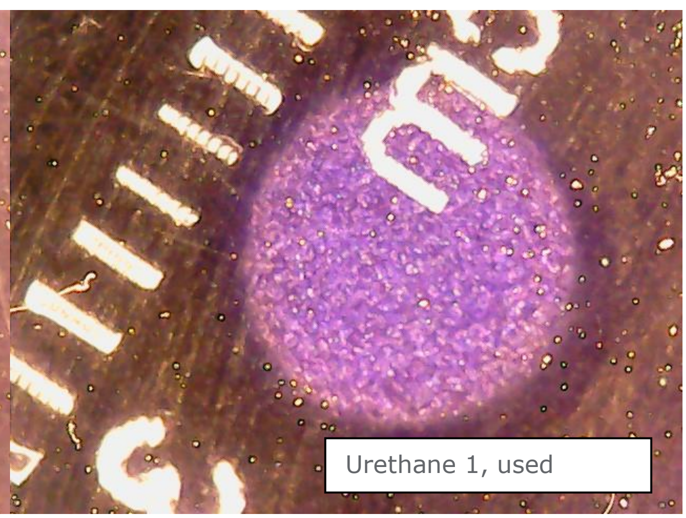
- Manufactured hardness strongly relates to footprint diameter.
    - 1 point in hardness, moves the footprint diameter approximately 0.008”.
- Footprint change with use for both urethane ball types was 0.008”.
- Hardness change with use for each urethane ball type was different (3.7 D and 2.6 D respectively).

We know oil, shear forces, temperature and a handful of other factors contribute to the changes we see with hardness. The fact that both sample types footprint changed by the same amount with use is quite interesting. The answer appears to be in the oil. Despite these samples being cleaned and resting overnight before being retested, the images clearly show that the footprint testing after use could identify lingering residue on the ball. Any residue present in the contact area will naturally get squeezed outward as the material deforms into the glass which would also have the consequence of making the footprints appear slightly larger.


Urethane 2, unused


Urethane 2, used


Urethane 1, unused


Urethane 1, used

Residue on the samples causing the footprints to appear slightly larger would explain why the footprints grew identically on average, despite having different drops in hardness. If a ball were to truly be produced at a hardness 3.7 D less than before, the production trend would expect the footprint to grow by 0.028”. Likewise, a change of 2.6 D should cause the footprint to grow by 0.020”. The data clearly shows that changes in footprint size of this magnitude are simply not occurring with hardness changes from use.

The repeat of the previous research is continuing to show that hardness changes with use are not impacting the performance of the bowling ball. Many factors contribute to the changes in hardness, but the data illustrates that the amount that the balls hook is not increasing. The overall ball paths are not changing. Reviewing footprint with regard to manufactured hardness levels shows there is a clear trend that harder samples have smaller footprints and softer samples have larger footprints. When this trend is applied to what we see with hardness changes and footprint changes due to use, hardness changes from use and hardness changes at production are two very different things.

KEY FINDINGS

- A repeatable SOP was prototyped and utilized to measure footprint diameters of bowling balls.
- A bowling ball's production hardness and footprint size are strongly correlated to one another.
- Balls that measure softer through use do not exhibit a strong correlation to change in footprint.
- This study reinforces that urethane bowling balls dropping in hardness measurements through use does not impact ball performance on the lane.

ACKNOWLEDGMENT

USBC thanks Cameron Hurwitz and Magnum Bowling Products for its research and publications in this area of study. Magnum shared details of a Footprint Measurement Gauge in its November 10, 2020 report titled "The Investigation of the Preservation Effect of the Immortalizer® bag enclosure on Bowling Balls' Physical Properties and Lane Engagement Performance over Time". Magnum's publication was helpful in the development of the USBC's SOP in this report.