Durometer Testing on Small Polymer Samples

Durometer testing is a quick and effective method to determine the hardness of a polymer material, which is often critically important to part performance. For example, an O-Ring that is too hard can result in a poor seal and cracking, and one that is too soft can show accelerated wear. Shore A and Shore D hardness testing can characterize the hardness of polymers from soft rubbers to rigid plastics through the procedure documented in ASTM D2240. This method requires a sample that is flat and at least 6 mm thick and 24 mm across, unless it is known that identical results are obtained at lesser dimensions. Those dimensions exclude many small polymer parts like O-rings or ball bearings. While a representative, larger coupon can be measured in place of a smaller part, this will not account for manufacturing process effects that can influence material properties in a finished part, and it will not account for the influence of a product's final dimensions and design on its apparent properties. With careful sample preparation and handling, reliable results can be obtained using a handheld durometer for samples smaller than 6 mm thick and 24 mm across.

Ebatco's Nano Analytical and Testing Laboratory (NAT Lab) is equipped with Mitutoyo Shore A and Shore D durometers. Each instrument has an indenter tip of known geometry attached to a calibrated force spring. Shore A and Shore D durometers use different geometries in order to cover two different hardness ranges. Shore A hardness characterizes soft to semi-rigid rubbers and elastomers, like rubber bands and shoe soles, while Shore D characterizes hard rubbers and plastics, like hard hats and golf balls. During a measurement, the indenter tip is pressed to the surface of the sample. The displacement of the tip and the spring constant of the internal spring are used to calculate the hardness of the sample as a dimensionless quantity from 0 – 100 for each range.

To determine the effectiveness of durometer testing on samples smaller than ASTM D2240 specifications, nitrile rubber O-rings and PTFE spheres of varying size were tested for Shore A and Shore D hardness, respectively. The O-rings and spheres were tested at two different locations; each sample was tested on its apex, and on a flat cross section that was cut from each sample. For tests at the apex, measurements were taken on the product as-is, so the thicknesses are equal to the listed diameters. O-ring cross-sections were cut so the thickness was equal to the wall diameter, and sphere cross-sections were cut so the thickness is equal to half the diameter.

Table 1 Test Results for Nitrile Rubber O-Rings and PTFE Spheres

Specimen	**Nitrile Rubber O-Rings (Shore A)**			**PTFE Spheres (Shore D)**		
Diameter	**1/16" (1.6 mm)**	**3/32" (2.4 mm)**	**1/8" (3.2 mm)**	**1/4" (6.4 mm)**	**3/8" (9.5 mm)**	**1/2" (12.7 mm)**
Apex Hardness	66.9	68.1	69.4	54.4	55.7	55.5
S.D.	3.8	3.7	2.0	2.5	2.4	1.6
Cross-Section Hardness	72.3	72.6	70.4	51.9	53.2	54.0
S.D.	1.9	2.2	0.9	1.5	0.8	0.9

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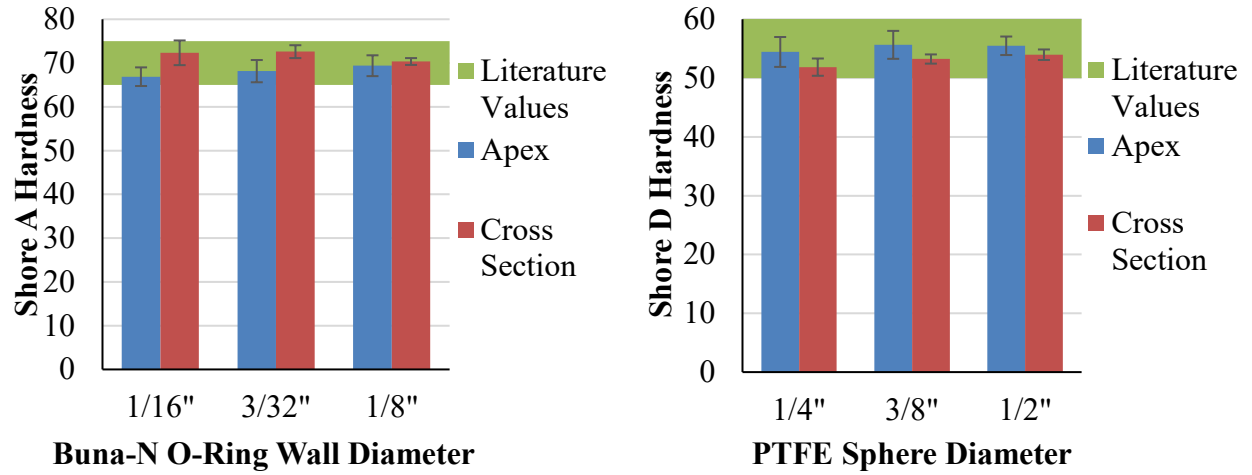


Figure 1. Shore A results for nitrile rubber O-rings (left) and Shore D results for PTFE spheres (right) tested on the apex and cut cross section of each sample.

The Shore A and Shore D hardness results are shown in Table 1, and Figure 1 shows the comparison of these results with literature values. The O-rings have a manufacturer listed Shore A hardness of 70 ± 5, and the PTFE spheres have a listed Shore D hardness of 50-65. The durometer results fall within the literature value ranges for each specimen, demonstrating that it is possible to produce reliable results with samples that are smaller than the size listed in ASTM D2240. The Shore A hardness results showed a slightly increasing deviation from the nominal hardness value as the sample dimensions decrease for both the Apex and Cross-Section tests, but the divergence was relatively small. For Shore D hardness results, the Apex tests maintain a mean value at the middle of the range, indicating that reliable results can be obtained for curved samples with lateral dimensions less than 24 mm. While Shore D hardness results for the Sphere Cross-Section samples stay within the specified range, the decrease in hardness with decreasing diameter and thickness indicates decreasing accuracy for Shore D testing on samples thinner than 6 mm.

The results show that it is possible to produce reliable results with samples much smaller than 6 mm thick and 24 mm across. This allows for small parts to be measured as-is, rather than measuring a larger coupon of the same material, ensuring that any changes in hardness from the manufacturing process of the small part are measured. It is imperative to understand the properties of the final product when manufacturing critical components such as O-rings or ball bearings, to ensure optimal performance. While all Shore A and Shore D hardness results fall within specified ranges, it is recommended to establish the relationship between sample size and durometer hardness results for a more complete understanding of a given material. This recommendation is supported by the Shore D testing that shows a minimal effect on hardness from decreasing sphere diameter on samples tested at the Apex, but a more noticeable effect of decreasing sample thickness in the Cross-Section tests. ASTM D2240 provides sample dimensions that will reliably and accurately measure hardness values, but the testing results presented here indicate that accurate results can still be obtained on smaller samples, albeit with a slightly higher uncertainty.