Comparison of results and test methods using the Micro IRHD and the Micro Shore rubber hardness measurement instruments

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Abstract

Rubber hardness can be determined using either the IRHD (International Rubber Hardness Degree) or the Shore Scale. The test methods and instrumentation for each are distinctly different, for example in the time and method of indentor application and geometry. This paper is concerned with the micro versions of these test methods – normally used to measure small samples. Instrumental parameters and sample limitations of both methods were investigated. The paper illustrates the practical differences between the tests, their limitations and the effects on the results obtained, providing valuable information of the advantages and disadvantages shown by each test method.

Introduction

Hardness measurement is one of the most commonly used methods in product testing and quality control. Two test scales are commonly used, providing results on either the IRHD or Shore scale. A number of instrument types exist for both - the IRHD dead load and Shore-A scales are most commonly used for rubber. Both methods are described in international standards.

The IRHD test is usually non-destructive, and as such has to be the preferred method for final product inspection; the test takes 35 seconds. In contrast, the Shore method is often destructive (leaving a permanent indentation), but only takes 1 (or 3) seconds. It is recognised that although there is little relationship between the two tests, there can be a degree of correlation over certain hardness ranges for some compounds. Both methods have been used for decades, yet Briscoe and Sebastian[1] (1993) report that the Shore-A test has not been subjected to the sort of detailed analysis of the IRHD method. Their paper looks at the Shore-A test and concludes with an approximate relationship of Shore-A and dead load IRHD hardness. Brown and Soekarnein[2] carried out work in 1991 investigating the reproducibility of Rubber Hardness Tests on both the IRHD and Shore-A scales. The instruments used were analogue, lacking the precision of modern electronic models.

The IRHD scale has a micro counterpart - for which a standard has existed for over 30 years (ISO 48[3] & ASTM 1415[4]). The proposed Shore Micro does not yet have a released standard. The Micro IRHD instrument was devised in the 1950's as a scaled down version of the dead load for testing thinner, smaller samples and products (such as 'O' rings). The Micro IRHD results are generally comparable to those given by the standard dead load IRHD instrument. In contrast, there are various 'Shore-M' scale hardness testers appearing on the market. The results are not comparable to those given by the Shore-A scale. Also, little is known about the Shore-M scale, its relationship to the Micro IRHD scale and instrumental differences.

This paper is concerned with both micro instruments. Experience has shown that, in practice, a degree of confusion exists between users of the two test methods. Also, it is not always possible for tests to conform exactly to a standard due to sample size and shape constraints. Whilst comparing the two methods, the paper's objective is not to determine a relationship between the micro scales, but to illustrate the practical differences between the tests, the results obtained and some of the instrumental parameters involved.

In order for this paper to be written, Wallace manufactured a Shore-M instrument, to currently available information. This instrument is compared to the standard Wallace Micro IRHD hardness tester.

Differences between the Micro IRHD and Shore-M Instruments

The Micro IRHD instrument uses a spherically tipped indentor. A sharp conical indentor is used for the Shore-M instrument.

The micro IRHD is based on the use of dead loads. The test uses a foot to hold the sample in place with a force of 245mN. A primary load of 8.3mN is then applied for 5 seconds, providing a datum position. A secondary load of 145mN is then applied for 30 seconds. The incremental displacement (from the datum) is measured and converted to an IRHD value (a non-linear scale defined in the standard). The maximum indentation depth is 0.3mm.

In contrast, the Shore-M test uses a calibrated spring (applying varying forces of between 0.3N and 0.8N) to supply an indentation force and the indentation force increases linearly with indentor displacement. The presser foot applies a force sufficient to overcome the spring force. Once the presser foot contacts the sample, the indentation depth is recorded after a set time. The maximum indentation depth is 1.25mm. The standard dwell times for the Shore-A scale are 1 and 3 seconds. These are also used for the Shore-M test. Each durometer point on the Shore-M scale represents 0.0125mm displacement.

Experimental

The Wallace Micro IRHD and Shore-M instruments were calibrated before starting the test sequence and rechecked at the end. The standard temperature of 23 ± 2°C was used, except where otherwise noted. Each test was carried out on the Micro IRHD and the Shore-M instruments in sequence, with the Shore-M instrument using either a 1 or 3 seconds dwell time (timed to ± 0.1 s). Each sample was tested in 5 different places.

Four standard Wallace test blocks* covering the range 40 to 80 IRHD were used to provide comparative results for each instrument. Additionally, a variety of rubber samples were tested on both instruments.

The nature of the micro test implies the use of small samples. The effects of sample thickness were investigated by carrying out tests on thinner samples. Although ISO 48[3] allows 1mm thick samples to be used, the preferred thickness is 2 ± 0.5mm and the standard recommends that two or more samples be plied together to conform to the requirements. It is known that the Shore-M scale has similar requirements. Tests were performed on 1, 2 and 3mm thick samples. A latex surgical glove of 0.1mm thick was used as a sample with up to 15 pieces plied together in incremental steps to determine the effect on the results.

* The standard Wallace test blocks are varying compounds of natural rubber, supplied by MRPRA.

The Wallace test blocks are approximately 25mm × 25mm. To meet the standard[3], the indentor must be at least 2mm from the edge of a test piece. This requirement was investigated by reducing the size of a standard sample (initially quartered and then reduced by regular amounts). Since 5 tests are performed on each sample, the minimum size sample required to conform to the standard is approximately 6 × 6 mm. The sample was further reduced to measure the effects of decreasing the size below the standard specifications.

A bent sample can give an apparently softer result since the load deflects the sample before indentation occurs. The foot force of the Shore-M scale is much larger and this effect was examined on both instruments.

The effects of temperature on the test was compared by operating both instruments at 33 ± 2°C. Both instruments and samples were kept in the same environment.

Since tests may be conducted on a previously measured spot, the effect of repeated measurements on the same spot was investigated for both instruments.

Since it is known that in the case of the Shore-M instrument the foot load simply needs to overcome the spring force, it was decided to investigate the effect of altering the applied foot force (presser foot weight). The Shore-M foot force was applied by a 514g weight; this was reduced to 152.5g. Weights were added in increments of 50g to a maximum of 350g, applying a total weight of 502.5g. Tests were carried out on the standard Wallace blocks at each increment.

A microscope was used to view the indentations (immediately after testing and after elapsed time) produced on different samples using both instruments.

Results

Standard test blocks

The standard Wallace blocks[*] gave repeatable results on both instruments. The 1 and 3 second Shore-M dwell times produced equivalent results with an increasing tendency to deviate from the IRHD result with increasing hardness values. See figure 1 below.

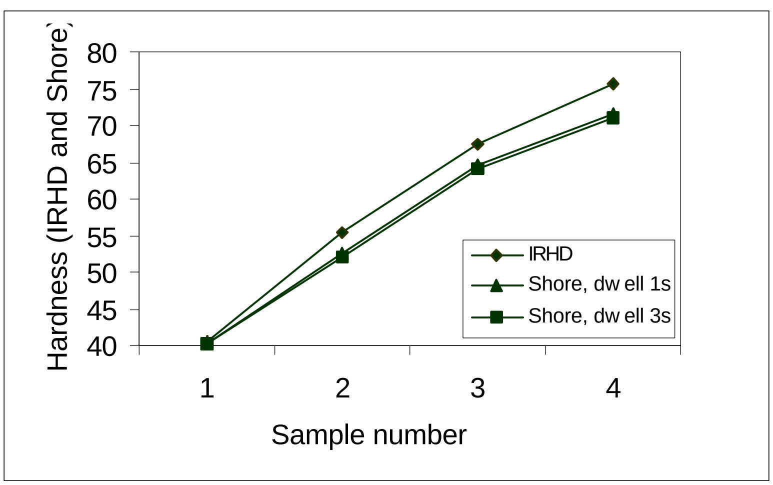

Figure 1. Increasing deviation between IRHD and Shore scales with increasing hardness

Variations between different sample types

Generally, different rubber samples gave repeatable results (table 1) on both instruments. Additionally, the average results were consistent between instrument types and Shore dwell times. However, some anomalies were noticed when testing with the IRHD instrument. These were found to be due to imperfections in the sample and the samples' lack of flatness. In contrast, the same effects were not seen with the Shore-M results.

	Standard Deviation (to nearest d.p.)		
Sample	IRHD	Shore, 1s	Shore, 3s
Butyl	1.6	1.1	0.9
EPDM	0.9	2.9	1.6
Nitrile	0.7	0.3	0.2
Natural	0.6	1.0	0.6
Chloro compound	13.6[H]	0.5	1.1
Nitrile/PVC	1.0	0.4	0.8
EPM	0.7	0.4	0.2
NBR	1.4	1.3	1.3
Silicone	2.4	2.0	2.3
FKM	0.9	0.3	0.6

Table 1. Samples tested with their standard deviations

Effects of thickness

As expected, different results were obtained with 1mm, 2mm and 3mm thick samples. There was a general decrease in hardness value with increasing thickness, but all results were repeatable. See figure 2.

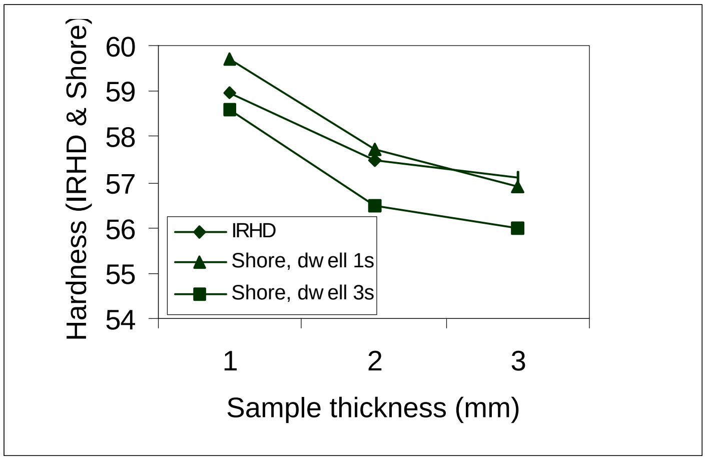

Figure 2. Example of decreasing hardness with increasing thickness for an unspecified rubber type.

[H] An example of an anomaly due to sample imperfections and the sample's lack of flatness.

When testing samples of 0.1mm thickness, more than one piece was plied. Generally, the results of each plied thickness deviated little from the mean although a few anomalies were noted. These are believed to be due to the number of tests carried out on the top piece of rubber and samples flatness. The sample hardness value decreased with increasing thickness. Initially, the Shore-M results were about 10 IRHD units higher than those produced on the Micro IRHD, but once the sample thickness increased to 1.54mm, the results were comparable (fig. 3).

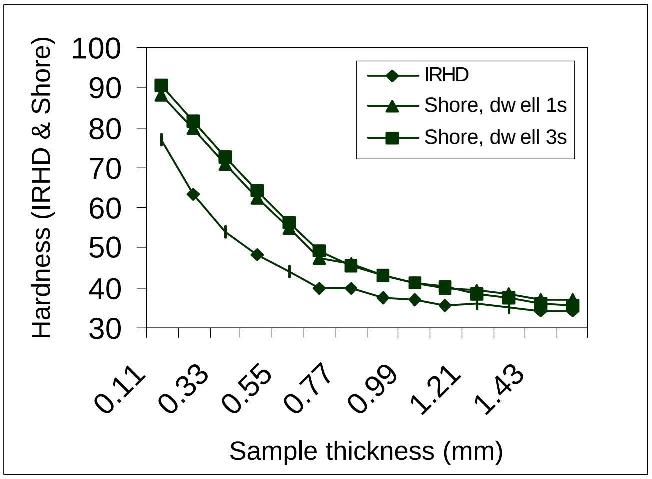

Figure 3. Increasing the thickness of a latex surgical glove of initial thickness of 0.1mm

<u>Effects of lateral sample dimensions</u>

Despite reducing the sample size, the results on both the instruments were found to be repeatable. The results on the Micro IRHD were generally consistent for the softer rubber (40 IRHD). However, the Shore-M instrument gave rapidly increasing hardness values with decreasing sample size (up to a maximum difference of approximately 15 units). Although the 50 IRHD sample gave similar results, the Micro IRHD tended to produce decreasing hardness values with decreasing dimensions (to a maximum hardness difference of 3.5 units). In contrast, the Shore-M results exhibited the same upward trend as before (but with a reduced maximum hardness difference of approximately 7 units). The 65 IRHD sample tested on the Micro IRHD decreased at the same rate as before, while the Shore-M instrument exhibited more stable results despite a few fluctuations. Finally, the hardest sample tested (70 IRHD) on the Micro IRHD instrument exhibited a general downward trend (a maximum difference of approximately 4 IRHD). Conversely, the Shore-M instrument produced more stable results between the dimensions tested, with a slight upward trend, of about 1.5 units. The two figures below (fig. 4 and fig. 5) show the extreme cases as discussed above, namely the softest and hardest rubbers.

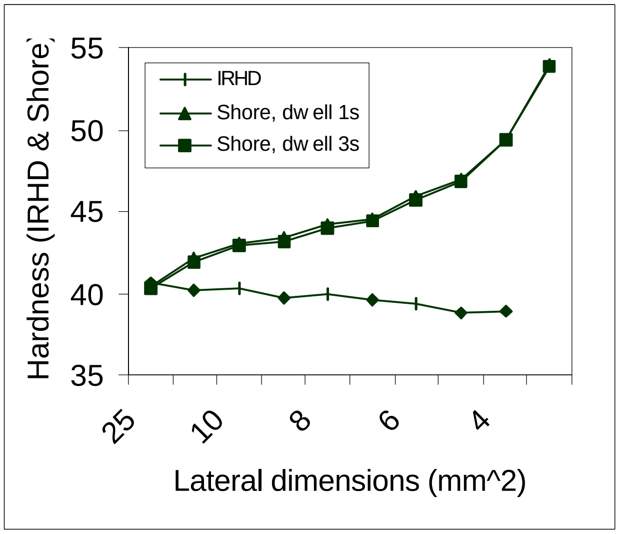

Figure 4. Extreme differences in results between IRHD and Shore-M tests when reducing the dimensions of a sample of about 40 IRHD.

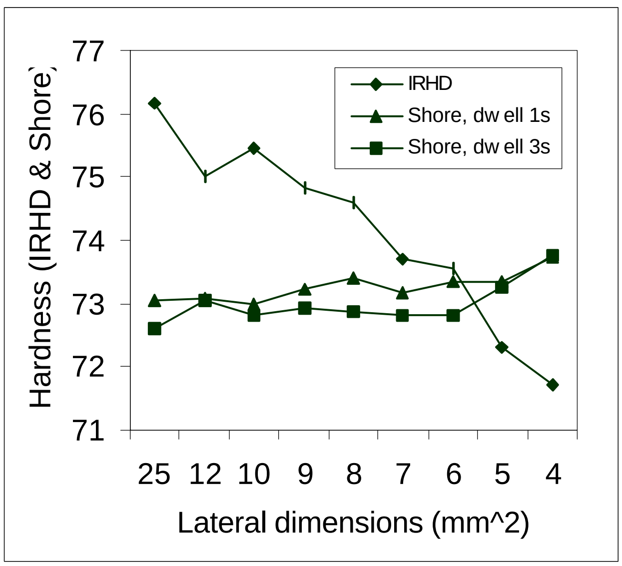

Figure 5. Extreme differences in results between IRHD and Shore-M tests when reducing the dimensions of a sample of about 74 IRHD.

Effects of sample flatness

Tests were carried out on bent samples to determine the effects on both instruments. These tests showed that for softer rubbers (40 and 50 IRHD), the samples quickly recovered to the 'flat' state and there was little difference between IRHD and Shore readings. For harder samples (60 and 70 IRHD), the Shore-M instrument gave consistent results, independent of the state of the sample, but the Micro IRHD instrument gave much lower values. In an extreme case, a 70 IRHD sample showed a difference of 30 IRHD between its 'flat' value and 'bent' values. In fig 6 below, each collection of 3 points is for each of the 4 standard Wallace blocks. In each case, the first of the three points is a test on an unbent sample, the second is a test on a previously flexed sample and the third is a test on a sample which has been kept bent for 10 minutes.

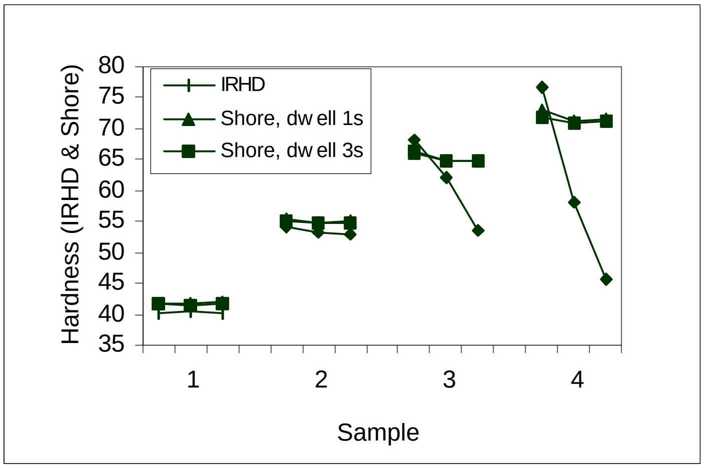

Figure 6. Harder samples being more affected by bending than softer samples.

Effects of temperature

Increasing the temperature to 33 ± 2°C made little difference. The softest sample (40 IRHD) didn't show significant changes on either instrument. The 60 and 70 IRHD samples exhibited a decrease in hardness of 1.5 units on the Micro IRHD and 0.8 units on the Shore-M. The hardest sample (80 IRHD) exhibited the greatest effect, showing a decrease of 2.4 units for the Micro IRHD instrument and a decrease of 1.5 units for the Shore-M instrument. Observations were made on a variety of samples and although repeatable results were obtained, no general trends were observed with increased temperature.

Effects of repeated testing in one location

The same spot was repeatedly measured. There was a decrease in hardness with increasing number of tests shown on both instruments. However, the Micro IRHD instrument gave more stable results, with only a total decrease of 1.5 IRHD over 28 tests on a rubber of approximately 65 IRHD. In contrast, the Shore-M instrument results decreased much more rapidly before levelling out. The total decrease was approximately 5 units over 28 tests on the same sample. It was also noted that results produced from 1 second dwell time were consistently lower than those produced with a 3 second dwell time on the same sample. These results are represented graphically in figure 7 below.

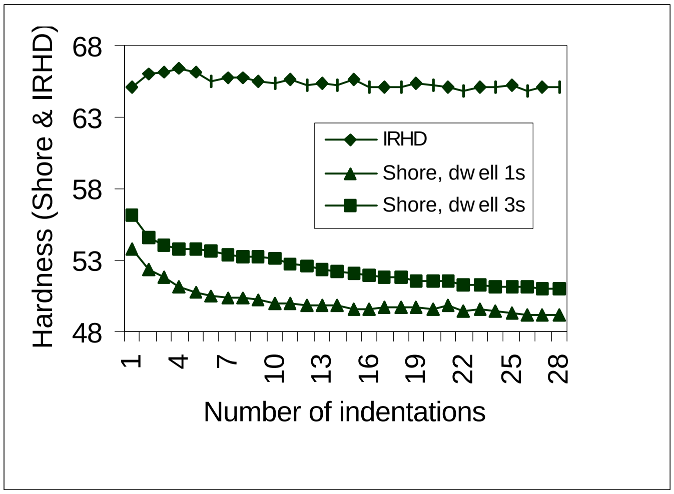

Figure 7. Repeated testing in one location

Effect of altering the Shore-M foot force

In general, increasing the foot force appeared to produce increasing hardness. The effects were small on the samples tested.

Observations of the sample surface after testing

Although all samples previously tested were observed for surface effects, particular attention was paid to a small selection, namely silicone, a fluoro compound, EPDM, a chloro compound and the standard Wallace test blocks. Immediately after testing, the indentation left by the Micro IRHD instrument can be seen by eye. After a few minutes the indentation disappears, illustrating the non-destructive nature of the Micro IRHD test. In contrast, the samples tested on a Shore-M instrument exhibited a clear indentation immediately after testing both to the eye and under the microscope (see fig. 8). These indentations were also observed about 2 hours later. The same indentations can still be seen a week later, demonstrating a permanent deformation experienced by samples tested on a Shore-M instrument.

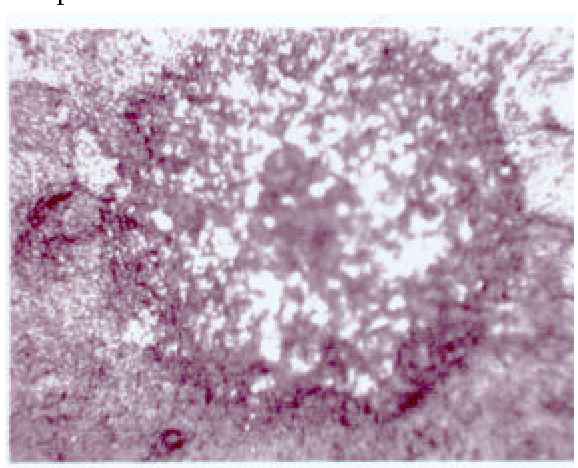

Figure 8. Photograph of an indentation left on the fluoro compound after being tested on the Shore-M. The magnification used here is 350×.

Discussion

As expected, very thin samples of non standard thickness influenced the results taken on both instruments. This is due to the influence of the supporting table and with increasing sample thickness, the effect becomes less apparent.

While the Micro IRHD results remained essentially constant for all lateral dimensions and hardnesses values tested, the Shore-M results showed that the apparent hardness rapidly increases for decreasing sample dimensions on the softer rubber, but less so for harder samples. Again the Micro IRHD exhibits a clear advantage.

The degree of sample 'bend' is important and its' different effects are very much apparent between the two instruments. Harder rubbers are more affected by lack of flatness on a Micro IRHD instrument, due the small foot force involved. None of the Shore-M results exhibit fluctuations, since the foot force is large enough to flatten the sample, displaying a clear advantage for bent samples. Increasing the foot force (a heavier foot weight is supplied as standard) can lessen the effects on the Micro IRHD instrument.

Increasing the temperature by approximately 10°C appears to make a greater difference to IRHD results than Shore-M results, but the effect is small.

Repeated testing at the same location does make an appreciable difference to the results. This effect is more apparent when using the Shore-M instrument. This is important to realise when standard test blocks are used to check calibration.

The Shore-M result is relatively independent of foot force for a reasonable range of forces.

It is interesting to note that the results obtained from the Shore-M instrument with a dwell time of 3 seconds differ from those obtained using 1 second. Therefore, although the increased time used for comparative Shore-M tests is unimportant, it is important that the timing is accurate and repeatable.

Sample penetration is very much apparent in the case of a Shore-M Instrument whilst a Micro IRHD instrument is non-destructive and as such is suitable for testing end products. The disadvantage of the IRHD instrument is the time taken (35s specified by the standard). Previous work by Lackovic et al[5] (1997) indicates that this time can be reduced by a predictive technique taking it into direct competition with the Shore-M timing, i.e. 3 seconds.

Conclusion

This paper has revealed many differences between the two instrument types. Both instruments clearly exhibit advantages in certain areas. For example, for testing samples of small dimensions, a micro IRHD instrument would be the preferred choice. The Shore-M test would be the preferred instrument for testing 'bent' samples. Other important considerations when selecting a test method have been covered. These include the awareness of the sample penetration using a Shore-M instrument which becomes important when repeatedly testing a sample or calibration block and during final product testing. The need for accurate and repeatable timing is important in the case of the Shore-M instrument to provide consistent results. Once the Shore-M instrument has an associated standard, the user can choose an instrument that best meets his needs.

Additional Work

Additional work needs to be carried out, investigating the testing of curved samples such as ‘O’ rings, where instrumental differences might be expected to have an effect.

References

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