

Measuring hardness

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Hardness is one of the simplest and most descriptive of polymer properties. The number of measurement scales available can however cause confusion. The hardness of a material is essentially its resistance to indentation. Most instruments designed to measure hardness do so on the basis of the depth of indentation produced by a given force on a standardised indenter, with the reading displayed either digitally or on a dial.

A high reading usually corresponds to a high hardness (small indentation) and a low reading corresponds to a low hardness (large indentation). A material of low hardness is termed a 'soft' material. It is also found that hardness relates to flexibility with soft materials being more easily flexed and to cushioning where soft materials compress substantially to act as shock absorbers. These relationships make hardness a doubly useful measurement for shoe soles.

An important point is that a hardness reading is time-dependent, tending to reduce the longer the indenter is held pressed into the surface due to visco-elastic creep effects. A choice of reading times is therefore available which needs to be agreed between supplier and customer, and be stated alongside any test result or specification.

The amount of indentation and hence the reading, is significantly influenced by the shape of the indenter and the force applied to it. A range of different instruments is available, each designed to operate over a particular scale. Hard materials require fairly sharp indentors and a high force, with soft materials requiring blunter indentors and lower forces.

Use of the wrong instrument will give readings bunched together very close to one end of the scale, with no sensible discrimination between them. We will now examine the instruments and scales in common use and identify their distinguishing features, so that users will be able to recognise the most appropriate type to employ.

SHORE HARDNESS

Shore hardness meters or 'durometers' such as SATRA's STD 226 and 227, are both easy and convenient to operate and have proved very popular across the polymer and shoe industries. They are described in a number of indentation hardness methods, including ASTM D2240, ISO 868 and SATRA TM205. They rely on spring-loaded indentors which project 2.5mm out through a hole in the flat foot of the instrument. At full projection against zero resistance, the instrument reads zero. At maximum resistance, when the indenter is pushed back the full 2.5mm to be flush with the foot resting squarely on the specimen surface, the reading is 100. In between, the reading is linearly dependent on the penetration depth. It is vital that the instrument foot seats correctly on the surface of the test specimen, which itself must be flat and smooth. Any gap will result in falsely low readings – every 0.025mm is worth one point off the hardness reading.

While shore instruments can be used in a hand-held mode, considerable expertise is needed to avoid inaccurate readings, so it is better to use instruments mounted on stands. These offer a controlled application of the instrument to the specimen. However, they do require perfect specimens with a uniform thickness of at least 6mm, having parallel, flat and smooth top and bottom surfaces. Otherwise, gaps will form between the specimen surface and the instrument foot, thus leading to measurement error. The most difficult part of the hardness test is usually that of producing a satisfactory test specimen from complex moulded shapes. This is nevertheless essential if reliable readings are to be obtained.



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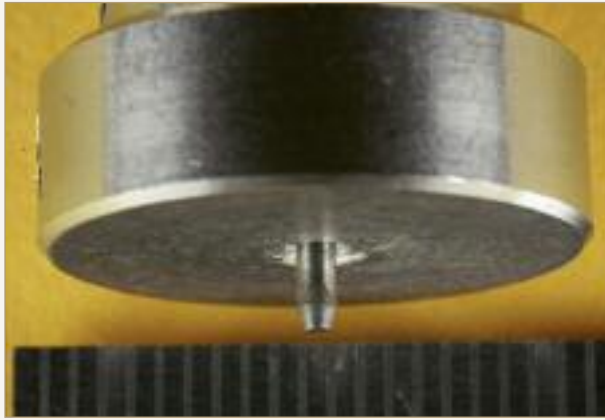


Figure 1 – Shore A indenter.

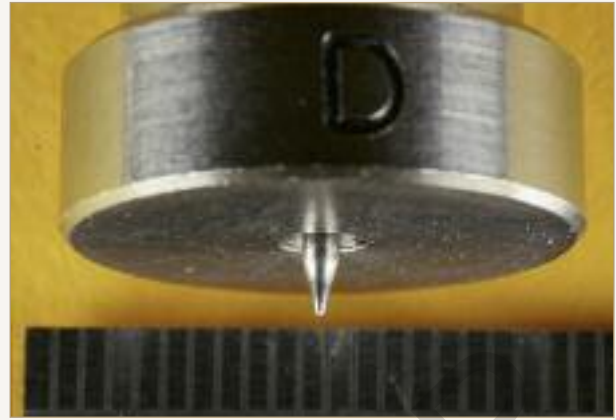


Figure 2 – Shore D indenter.

In footwear applications, the main Shore scale is 'Shore A', suited to flexible, compact polymers, including the majority of soling compounds. The Shore A instrument has a truncated conical indenter. The indenter diameter is approximately 1.3mm, which tapers down to a 0.8mm diameter flat tip with a 35° cone angle (Figure 1). The indenter spring exerts 8.05N at a reading of 100.

The 'Shore D' instrument is more suited to hard plastics such as those used in football soles and women's heel top-pieces (top lifts). The indenter diameter is also around 1.3mm, but this time there is a 30° cone running to a pointed tip with a 0.1mm tip radius (Figure 2). The spring behind this indenter exerts 44.45N (10lbf) at a reading of 100, sufficient to indent

hard plastics and impossible to overcome with a bare finger.

Shore B and C scales are also available, but neither are considered useful in footwear testing (Shore B uses the 'D' indenter with the 'A' spring, while Shore C uses the 'A' indenter with the 'D' spring). Sometimes Shore C is misquoted by customers who really mean 'Asker C', which is an entirely different scale (see below). Consideration of indenter shapes and spring forces should make it clear which instrument is, in fact, being used.

Soft foams can resist only blunt indentors with low spring forces and 'Shore OO' (Figure 3) has been found useful in many cases. This employs a hemispherically-ended 2.4mm diameter indenter and a mere 1.111N spring force at reading

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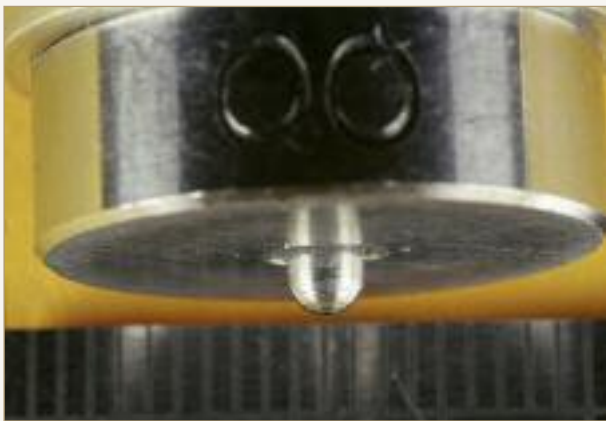


Figure 3 – Shore 00 indenter.

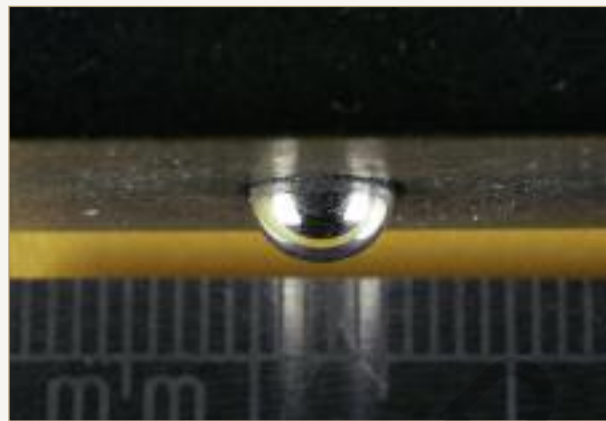


Figure 4 – Asker C and Shore E indenter.

100. An alternative, and increasingly popular scale for soft materials such as EVA midsoles, is the so-called 'Asker C', as mentioned. This is almost identical to 'Shore E', which has appeared in recent updates of ASTM D2240. Asker C and Shore E use a 5mm diameter ball on the end of a 4.5mm diameter rod (Figure 4). The Shore E spring force at reading 100 is 8.05N, which is the same as for Shore A. The Asker C spring force is 4 per cent lower, apparently the only difference from Shore E.

INTERNATIONAL RUBBER HARDNESS DEGREES

The international rubber hardness degrees system (IRHD), referred to in methods ISO 48, SATRA TM206 and ASTM

D1415, is still preferred in many types of work. It is even recognised in some Shore method documents as best suited for use in cases of arbitration or dispute. The IRHD instrument is more complicated than Shore durometers, but still gives readings on a scale up to 100 and will often give a close numerical similarity to Shore A readings (Table 1). The advantage of IRHD meters is that they effectively enable the meter to be 'zeroed' (in fact, set to 100).

This is done to reduce errors due to minor imperfections in specimen surfaces, under a very small load of only 0.3N. The hardness reading is taken after applying a further 5.4N loading. The normal IRHD instrument has a 2.5mm diameter ball indenter (Figure 5) and is distinguishable from Shore-type

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Table 1: Example comparisons between IRHD and Shore A scales

Material	Hardness IRHD 30 seconds	Hardness Shore A 3 seconds
PVC	74	73
TR	71	64
Resin rubber	93	94
Vulcanised rubber	74	69
PU	50	56
EVA	48	52

Table 1 – Example comparisons between IRHD and Shore A scales.

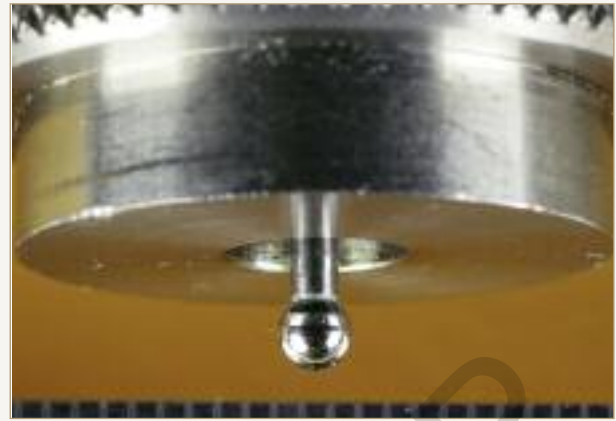


Figure 5 – IRHD normal indenter.



Figure 6 – IRHD low indenter

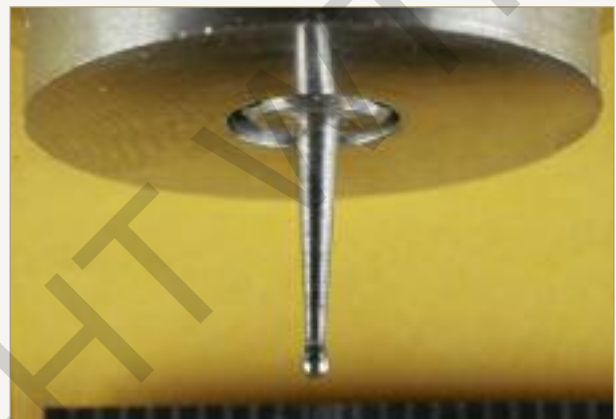


Figure 7 – IRHD high indenter.

indentors because it is retracted inside the instrument foot until the test is operated, although it can be inspected by pushing the foot upwards to expose it. A low hardness version of this test is available with a ball indenter of 5mm (Figure 6) and a high hardness test with a ball indenter of 1mm (Figure 7). These may be used at hardnesses below 35 IRHD and above 85 IRHD respectively.

INDENTATION TIMES

As well as specifying the scale used, it is crucial to record the indentation time in seconds at which the reading was

taken, as this significantly influences the result. Similarly, specifications must also give a time so that the tester knows what to do. Figure 8 shows the hardness-time relationship for an example material. Common standard times used with the Shore durometer scales include one second, three seconds and 15 seconds. The exception to this rule is the IRHD system, which always employs a 30-second indentation time (after setting the scale to zero within five seconds) and, therefore, this need not be stated. Figure 9 summarises the applicability of the different hardness scales for soft and hard materials. ❷

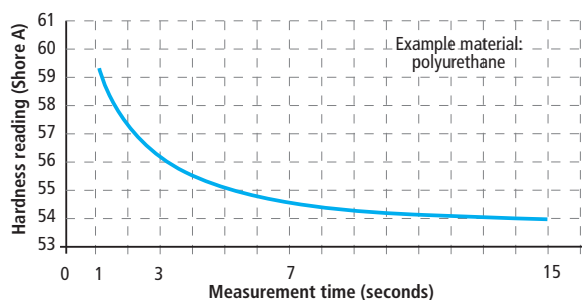


Figure 8 – Hardness reading versus measurement time.

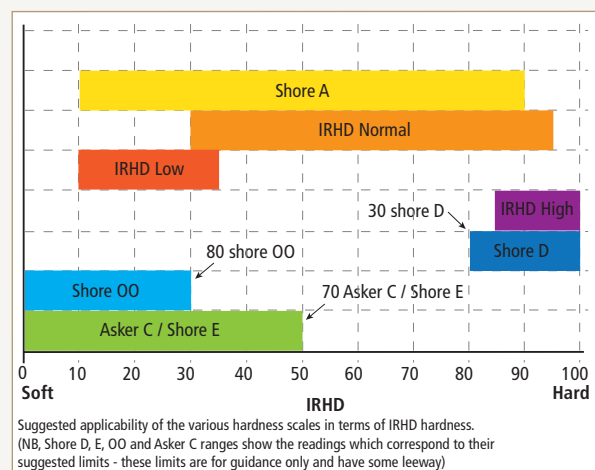


Figure 9 - Suitability of hardness scales.