Vickers vs. Knoop Hardness Testers for Measuring Case Depth in Carburized Parts

Email your question — along with your name, job title and company name (if you wish to remain anonymous, no problem) to: *jmcguinn@geartechnology.com*; or submit your question by visiting *geartechnology.com*.

QUESTION

What are the pros and cons of using Vickers versus Knoop hardness testers for measuring case depth in carburized gears?

Expert response provided by Dr. Michael Keeble. Both tests use a diamond indenter pressed into the specimen using a defined load and dwell time. After the removal of the load, the indent remaining in the specimen is measured optically.

The advantages and disadvantages of the two test methods come principally from the differently shaped indenters. Vickers testing uses a pyramidal diamond (Fig. 1) resulting in an indent with four nominally equal sides — or square-shaped. The diagonals of the square-shaped indent are both measured, and the average of those two values is used in the calculation of hardness. Knoop testing uses an elongated pyramidal indenter (Fig. 2), producing a rhombus-shaped indent. In this case, only the long diagonal is used in the calculation of hardness.

For both types of tests, there are practical constraints to consider; many of these are affected by the indenter shape.

Measurement accuracy. One of the largest sources of error in low-load Vickers and Knoop testing is the measurement of the diagonals. An error in measurement has a greater effect as diagonal measurements get smaller (with decreasing load or increasing hardness). For a 20µm diagonal, a 0.5µm error in measurement can result in a 5% error in the hardness reading. The Knoop test results in an indent more than twice the size of a Vickers indent for a given load. This by itself can improve the measurement accuracy by a factor of 2.

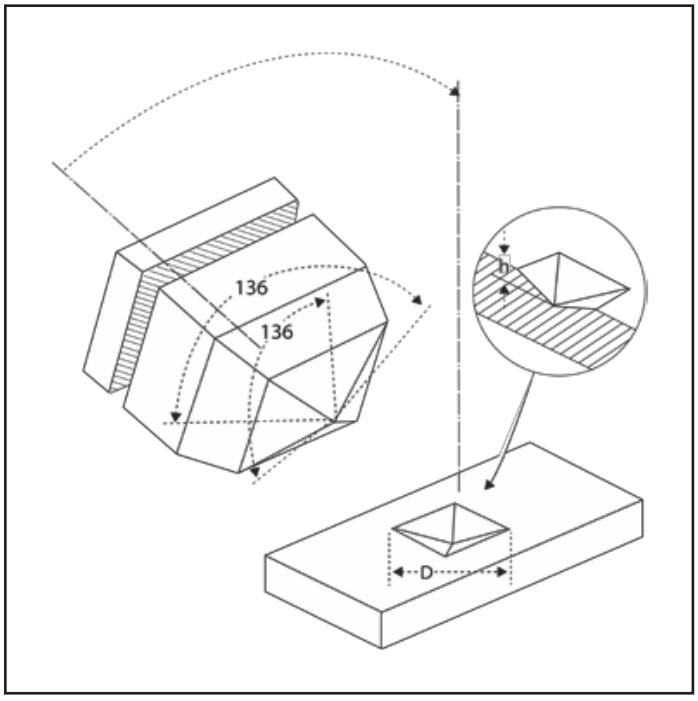

Figure 1 Illustration of the Vickers diamond indenter.

Indent positioning. Hardness tests are a measurement of the resistance to plastic deformation. When an indent is made in a ductile material, there is an area around the visible indent where deformation and stress are induced in the material. If that stress field is not fully within the undamaged material, you will get a different hardness reading. This means that the indent must be far enough from the edge of the sample, or even a different material within the sample. It also means that indents must be placed far enough away from each other that their stress fields do not overlap. Specific guidelines for minimum spacing are given in each of the ISO and ASTM standards, and are expressed in terms of multiples of the diagonal measurement of the indent. The opening angle of the Vickers diamond pyramid is defined in the standard as 136°, whereas the opening angle of the Knoop diamond pyramid is 172°. Thus, the depth of penetration is less using Knoop scales compared with Vickers, resulting in a less deep plastic deformation zone underneath and surrounding the indent. By aligning Knoop tests such that adjacent indents are made in line with the short diagonal, indents can be placed much closer together than using Vickers. Similarly, Knoop is ideal for tests on coatings. The difficulty with Knoop in some cases is correct alignment of the indenter with the specimen surface. This can be challenging if multiple case depth analyses are required in various positions around a curved surface.

Surface preparation. Surface preparation can affect the hardness reading in two ways. An irregular surface makes the edge of the indent more irregular, and can disguise the indent tip, making accurate measurement more difficult — especially for automated systems. In addition, surface deformation left from inadequate preparation can leave stress in the surface of the test material, which can change the hardness result. As the Knoop indenter is both narrower and shallower than the Vickers indenter, it will be more sensitive to surface preparation, given that a more carefully prepared surface is needed.

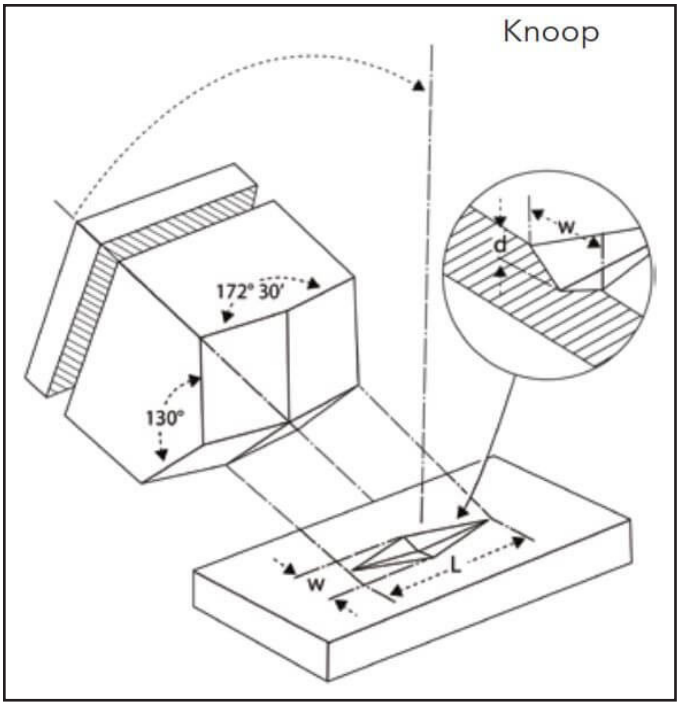

Figure 2 Illustration of the Knoop diamond indenter.

Conversion and comparison of test results. The Vickers test, in theory, gives the same hardness value for tests at all loads, due to the shape of the indenter; although in practice, variation tends to appear at very low loads, due to proportionally greater impact of variation in test conditions and measurement error. However, the Knoop test gives a different hardness when conducted at different loads. This can lead to constraints if conversion is required; Knoop conversion is restricted to 500gf tests or above—where included at all—in the ASTM E140 conversion tables.

Conclusions for carburized gears. It's usually an advantage to use Knoop testing to assess case depth in carburized gears. The ability to start indenting closer to the edge, to place indents closer together, and to improved measurement accuracy for a given load allows a far more detailed assessment of hardness change with depth. All of these are especially useful in quality-critical applications, process development, R&D and failure investigation. The use of Vickers is a perfectly acceptable alternative in applications where detailed measurement is less critical. The time saved in a high-throughput environment through reduced requirements for surface preparation, and easier placement of traverses on multiple locations of a gear, can make this a more practical option.

After a degree in Materials Engineering, **Dr. Michael Keeble** did a research Masters degree in Steel metallurgy and a Ph.D. in high temperature properties of aluminum and FE modelling of casting processes. After this, he worked in both Government and private research organizations in materials characterization, quality control testing and industrial process development. For the last 15 years he has been working with Buehler supporting metallographic characterization and hardness testing method development and product development. Keeble gives lectures and training courses globally, and is the current vice president of the International Metallographic Society, as well as working with industrial and national standardization bodies (ASTM and ISO).