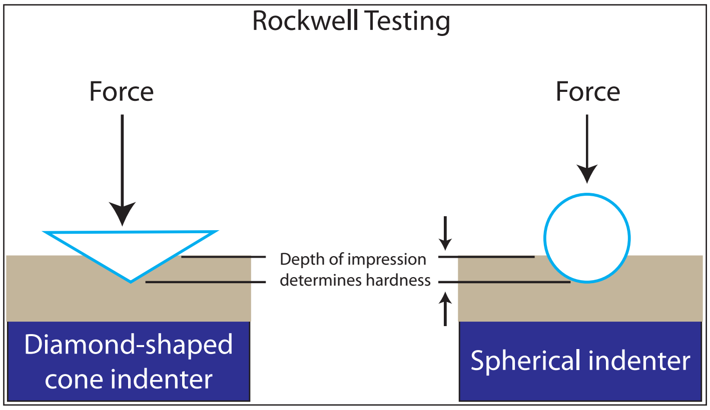
Hardness Testing



Specifying the hardness of finished gears is just one way that gear engineers can ensure they are made of the right material and properly heat treated. However, a wide variety of hardness testing methods exists. Here is a brief introduction to those most commonly used in gear manufacturing.

Rockwell. The Rockwell hardness test was invented in 1919 by Stanley P. Rockwell, who developed his method as a nondestructive way to quickly, repeatably and reliably test the hardness of the bearing races made by his company.

Like all of the other major testing methods, the Rockwell test determines hardness based on the results of an indentation test, wherein a hard material is pressed into the test piece under a specified load.

Rockwell testing is done in two phases. First, a minor load is applied. This reduces the effects of surface asperities and establishes a zero reference point. Then, a major load is applied for a set time period, and released, leaving an indentation in the test piece. The testing device determines hardness based on the depth of the penetration.

There are many variables involved in Rockwell testing. The indenter can be either a diamond cone or a steel ball, and steel balls of varying diameters can be used, depending on the material to be tested. Also, different materials require different minor and major forces to be applied, resulting in 30 different Rockwell scales (named A, B, C, etc.). The scale most widely used for gearing is the Rockwell C scale, which covers most steels. In addition, there is a Rockwell superficial test, which uses light loads and which is meant for thin or easily damaged surfaces.

ASTM E18 and ISO 6508 cover Rockwell hardness testing for metals. According to ASTM E18, Rockwell C hardness should be specified using the designation HRC along with the hardness number. The "H" stands for hardness, the "R" for Rockwell, and the "C" corresponds to the appropriate hardness scale. Thus, HRC 55 might be the Rockwell C hardness of 4140 steel.

Brinell. Swedish engineer Johan August Brinell invented the Brinell hardness test in 1900. It is often used on large parts, particularly castings or forgings whose grain structure is too coarse for testing via the Rockwell or Vickers methods.

With Brinell testing, a spherical indenter is pressed into the test piece and held for a specified time under a controlled force. The hardness of the piece is calculated based on the surface area of the indentation, which must be measured optically, either by microscope or by an optical device integrated with the tester.

Brinell testing is very much dependent upon the specific force applied as well as the material used for the indenter. Today, Brinell testing is typically done using 3,000 kgf and a 10 mm tungsten carbide ball.

ASTM E10 and ISO 6506 are the relevant standards for Brinell testing of metals. According to ASTM E10, Brinell hardness should be specified using the designation HBW, where "H" stands for hardness, "B" stands for Brinell, and "W" stands for tungsten carbide, the material used for the indenter. In addition, the size of the ball and the force applied should be included with the specification. Thus, an HBW 10/3000 hardness of 187 would indicate a Brinell hardness of 187 was achieved using a 10 mm tungsten carbide ball, applied at 3,000 kgf. Often materials suppliers and manufacturers leave out this important information, even though Brinell hardness numbers obtained using different forces or indenter materials are not comparable.

Vickers. The Vickers hardness test was developed in England in 1921 as an easier alternative to Brinell testing. It uses a standardized indenter, and the results are largely force independent (although there are special considerations for microindentation tests done at forces of less than 200 g).

Like the Brinell test, the Vickers test calculates hardness based on the surface area of the indentation. However, the Vickers indenter is a pyramid-shaped diamond rather than a ball. The diamond tip is pressed into the test surface under controlled force for a specified period of time. The Vickers hardness is a function of the test force divided by the surface area of the indent.

The Vickers test has two distinct force ranges: macro (1 kg–100 kg) and micro (10 g to 1,000 g). ASTM E384 covers the micro force ranges, while ASTM E92 covers the macro force ranges. ISO 6507 covers both ranges.

Knoop. The Knoop hardness test is used for particularly thin or brittle materials, where only a small indentation can be made. The Knoop test is similar to the Vickers test, except that it uses an elongated pyramid indenter and is reserved for microindentation testing.

Because the indentation is very small, and optical identification of the surface area is required, the Knoop test requires a highly polished, flat surface. This often means the test piece must be destroyed in the process.

Knoop testing is described by ASTM E384. Because it is force-dependent, it is crucial that the Knoop hardness specification include the testing force. Thus, HKN50 500 is the proper designation for a Knoop hardness of 500, achieved at 50 grams testing load.