



Fundamentals of Hardness Testing of Fasteners



Although it is likely that few individuals outside of the fastener industry possess an appreciation for fasteners, the reality is that fasteners, even ones we consider “simple” are sophisticated engineered devices. Since fasteners are so crucial in holding everything together, it is important that suppliers and users can verify that the fastener will perform the way that it is intended. To this end, fasteners that have been heat treated to meet desired performance requirements must be examined to verify that they meet the standards and will fulfill these specific requirements. One of the more important verification methods is hardness testing.

This article will explore the fundamentals of hardness testing of fasteners. In addition to gaining insight into what hardness is and why it is a useful test, we will explore the different methods that may be employed to conduct hardness testing.

..... What is Hardness?

Hardness is a measure of a material’s resistance to plastic deformation when subjected to indentation. It is also commonly considered as the ability to resist scratching, abrasion, cutting, or deformation when a load is applied. The harder a material is the better it can resist these sorts of damage. Hardness is often a function of multiple variables and other material properties such as ductility, stiffness, strength, toughness, and viscoelasticity. In simpler terms, however, we generally recognize materials as being hard or soft, and when it comes to fasteners, we often associate the degree of hardness with the presence or absence of manufacturing processes such as annealing, quench and tempering, or case hardening. We recognize, for example, that high strength, quench and tempered parts are harder than lower strength, annealed parts.

..... Why do we measure hardness?

With many materials, and specifically steels, there is a good correlation between hardness and tensile strength. Strength, as a general concept, is defined as the material’s capacity to handle applied stress. Tensile strength is the maximum amount of tensile stress a material can withstand before it breaks. Although hardness testing does not as accurately correlate to yield strength and ductility, hardness testing conducted properly and found within specification becomes a good predictor that the other material properties will also be in specification.

When verifying that a fastener can meet its minimum tensile strength requirements, it is best to conduct a tensile test. However, with parts that are too small to be properly fixtured in a tensile test frame, a hardness test becomes the only reliable predictor of the fastener’s tensile strength ability. Thus, hardness testing on fasteners is quite common, as so many fasteners are simply not able to be tensile tested. Additionally, hardness testing is fast and efficient, so that it can be successfully deployed as an in-process monitoring step. In other words, fastener manufacturers and their heat-treating vendors may employ hardness testing during the process to ensure that parts are staying within specification.

..... Hardness Testing Types

Hardness testing is conducted by pushing a uniquely shaped indenter with a very well-defined load into the part. These test methods fall into two broad categories: macro hardness testing and microhardness testing. Macro hardness tests are conducted with large indenters and loads and can usually be seen by the naked eye. On the other hand the use of light loads and small indenters results in



an indentation invisible to the naked eye. These are referred to as micro hardness tests.

For general purpose testing, macro hardness testing is what is usually employed. There are multiple different test methods including Rockwell B and C, Macro Vickers, and Brinell that commonly get employed on fasteners. In these tests, the size of the indenter and the load applied are large and leave a mark that is visible to the eye.

When delicate or very thin sections need testing, micro hardness testing is employed. This includes hardness tests on the outer case sections of surface hardened fasteners. Often these case-hardened sections are very thin, and the loads exerted by a macro hardness test would be too severe and the indenter would pierce through the area of interest resulting in errant or false measurements. Micro hardness is also often deployed during experimental research where multiple groupings of test sites within small areas are desired. Micro hardness testers use light loads, and the indentations must be analyzed under magnification.

..... Hardness Testing Methods

In addition to these two distinct categories of hardness testing, there are multiple different methods. Each method usually has its own unique scale associated with the obtained test results. Although there are conversion tables between these different methods, it is not always exact and anytime that one method must be converted to a different method, care should be taken.



Rockwell Hardness:

In North America, the most common hardness testing method for fasteners is the Rockwell test. Although Rockwell scales run from A to G, steel fasteners are evaluated exclusively with either the Rockwell B scale or Rockwell C scale. The Rockwell B Scale uses a 1/16" diameter round ball and 100 kgf load. The Rockwell C Scale uses a 120° Diamond Cone and 150kgf load. Obviously the heavier the load the more capable

it will be to indent harder parts and thus, obtain an accurate hardness measurement. For this reason, the Rockwell B scale may be used on annealed and un-heat-treated parts while the Rockwell C scale is used on heat treated parts.

In the Rockwell test a small preload referred to as the "minor load" is applied to the indenter. The minor load is about 10kgf, a small percentage of the total applied load and effectively seats the tip of the indenter into the part. The remaining part of the load, the "major load", is then applied. Rockwell measures depth and takes just the distance between the depths of the minor and major load and applies an algorithm to convert the depth reading into a value along the appropriate Rockwell scale.

Rockwell also has an N Scale. This is the Superficial Hardness Scale, meaning that it is specifically for measuring case hardened parts. There are three N variations: 15N, 30N, and 45N. Each uses a diamond cone indenter and a 3kgf minor load. Thus, the major load for 15N is 12kgf, for 30N is 27kgf, and for 45N is 42kgf.

Vickers Hardness Method:

Outside of North America, the Vickers method tends to be favored for hardness testing of fasteners. This method is considered to be the "easiest" of the testing methods because the calculations are independent of the size of the indenter. In fact, the same pyramidal diamond indenter can be used for all materials regardless of the hardness of the part. The Vickers test results in a Vickers Pyramid Number (HV). This test is most often performed with light loads as a micro hardness test, but larger loads are possible for the macro test. Loads can range between 1gf and 100kgf.

Whereas the Rockwell test determines the depth of the indentation, the Vickers test measures the length of the diagonals obtained by the indentation. These are measured and applied to an equation to determine the HV value.

Knoop Hardness Method:

The Knoop hardness method is a microhardness test utilizing a pyramidal diamond indenter and 100gf load. With its indenter geometry, the Knoop test is perhaps the best method for very brittle or thin layer testing. Like the Vickers test the indentation is measured, but unlike Vickers which uses both diagonals, the Knoop calculation uses only the long side of the indentation.

Brinell Test Method:

Although the least common method for fasteners, the Brinell method is sometimes still employed. The Brinell indenter is a very large 10mm diameter ball and 3000kgf load. The resulting indentation is measured and applied to an equation to generate the resulting Brinell Number.



..... Fastener Testing

Hardness testing is most commonly employed as an in-process method during the heat treating of parts or as a final inspection tool at either the heat treating, fastener manufacturing, or end user. The processes that trigger a hardness check include heat treatments such as a strengthening quench and temper, case hardening, or annealing process. Quench and tempered parts will normally receive a Rockwell C or macro-Vickers check. Case hardened fasteners require a microhardness method, such as Knoop or micro-Vickers. Annealed fasteners usually receive a Rockwell B test.

..... In Summary

Hardness testing is an important and everyday test that all fastener suppliers employ. Regardless of the chosen method, they are all governed by consensus standard organization specifications, in particular ASTM and ISO methods. Although the test methods are common and straight forward, they must be conducted closely with these standard methods to assure the accuracy and quality of the test. ■

