POINT
COUNTERPOINT

Hardness– a Ubiquitous Measure of Materials Performance?

POINT

Practical failure analyses generally require the quantitative determination of hardness. Hardness is a "core" value. We determine hardness by a "practical" indentation method. The ASTM Standard Methods explicitly define how to measure hardness as an engineering parameter, including precision and bias. The "point" is that frequently hardness is measured correctly, only to be "converted" and interpreted improperly.

The subject of our dialogue centers around the application and use of ASTM Standards E 18 (Rockwell Hardness), E 140 (Hardness Conversion Tables) and E 384 (Microhardness). These standards detail the appropriate indenters, loads, and procedures.

In manufacturing, where most failure analyses are quickly and purposefully conducted, hardness is the first test. It's the low cost, minimum essential, definitive test. If the number falls in the appropriate range, case closed. Certainly, after checking a statistical sample of the problem parts and testing control components, hardness provides a good comparative index. If the part in question is steel, compositional and carbon analyses are prudent. The preliminary failure analysis confirms the hypothesis: "It has to be the *process*, because the *material* checks out just fine!

The relationship between microstructure and hardness is conceptually well established. Hall and Petch, for one, teach us that the square root of the inverse grain size correlates directly with hardness. However, heat treaters and machinists have fought intense, controversial, passionate battles regarding machineability. These intense discussions focus on lamellar pearlitic steels containing various percentages of spheriodite, retained austenite, or de-carburization. The machineability of non-ferrous alloys can hinge on uniformity, where duplex structures cause problems. Is hardness of any value, the frustrated parties exclaim! Experience teaches that the evaluation of microstructure is a necessary foundational prerequisite to validate the results of hardness testing, to enable the appropriate interpretation and resolve disputes.

Now, having measured hardness, checked the composition, examined the microstructure, surely we are prepared to convert the Rockwell scale numbers to Brinell hardness (BHN). Except when we actually measure the BHN it turned out to be different than the number of BHNs estimated from the conversion tables.

We frequently use microhardness correctly to measure case depth for nitrided, carburized, or components coated with electro-deposits, and advanced wear resistant coatings. Sometimes, when a party is not aware of the surface treatment, hardness tests are made. A Rockwell scale number should not be predicted blindly from the DPH, Knoop, or Vickers numbers using the conversion tables and vice versa. For example, a soft substrate created by subsequent thermal exposure in the service application may go undetected.

Although some metallurgists know that these restrictions and caveats are prudent, many users of the ASTM conversion tables are unenlightened as to the implications. Quality control, mechanical, or industrial engineering specialists also routinely use converted hardness numbers.

Many times we communicate the converted values without understanding the constraints and inherent limitations, or worse, specify that the original hardness measurement use a different scale.

Let's resolve to pass the word that hardness testing and casual use of the conversion tables are not an effective way to transmit quality control or engineering data.

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The intention of our continued dialogue in future columns is to discuss societal impact. To conduct a failure analysis without identifying discrepant parts, rejecting inadequate components, and integrating what we have learned from analyses to improve both future designs and manufacturing methods is to have failed our employers and society. Let's resolve to practice life cycle design engineering: As shown conceptually in the accompanying illustration, life cycle design engineering is an iterative design cycle – performance testing – redesign …"process."

The objective is to integrate the output of our performance testing and failure analyses data to justify and implement changes to our materials, methods, processes, inspection, and product engineering. Ultimately, the discipline of evaluation and redesign results in continuous improvement.

Case-in-Point

Hardness measurements, methods, and relevancy (interpretation) have been a significant issue in product liability suits and other disputes between suppliers and users. The case-in-point involves the simple admonition to use care in any written specifications: purchase orders, material certifications, in-process records, and engineering prints.

All hardness specifications should state the ASTM hardness method that is applicable, note the preferred location of the test, detail any surface treatments, and most importantly, specify an acceptance range. I recall a specific dispute where the heat treater used an R-15N test. The acceptance range was from 88 to 92 derived from a print. A claimed manufacturer's defect was based on "discrepant" Rockwell C-scale measurements ranging from 46 to 52. The testimony that "we always did it that way and have never had a performance issue in over 40 years" sounded self-serving to the jury. It was an expensive lesson that could have been avoided by specifying the softer core hardness (RHC) range for this case hardened component. Instead the print was interpreted as RHC 56 to 64.

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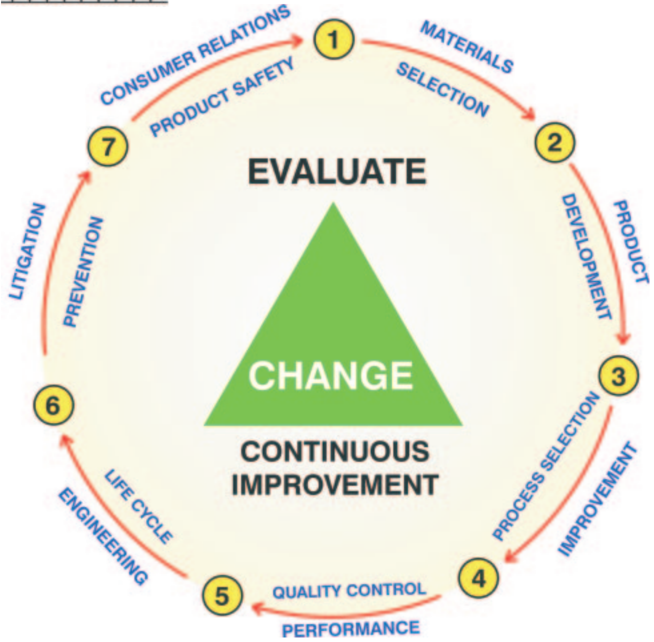

ASM and the author invite your comments on this article and suggestions for future topical issues.

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