MATERION

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TECHNICALTIDBITS

MATERION PERFORMANCE ALLOYS

HARDNESS VS. **STRENGTH**

Intuitively, most people have an understanding of hardness, even if they can't provide a metallurgically correct definition.

It's been a Hard Day's Night –
A brief discussion of the correlation, or lack thereof, between hardness and strength.

- ▲ Hardness
- ▲ Indenter
- ▲ Load
- ▲ Scale

Most people have an idea of strength as well, although most non-technical people may not be aware that any given material has a number of different properties that fall under the category of strength (yield strength, tensile strength, fatigue strength, impact strength, etc.) The terms "hardness" and "strength" may even be conflated for many people.

It is true that hardness and tensile strength correlate fairly well with one another. So, the first question that needs to be addressed is, "Can I use hardness test results to make any judgements on the strength of my material?" The short answer is "Yes" but take it with a grain — or ten thousand — of salt.

Perhaps it is best to start with the promised metallurgically correct definition of hardness. "**Hardness** is a materials resistance to permanent indentation by a given **indenter** at a particular loading condition." The bigger and deeper the indentation, the lower the hardness and vice versa. The 3 critical components of the test are the indenter (sharp object pressed into the surface), the **load** used during the test, and the **scale** (measurement system used to quantify the results.)

Hardness is really a quasi-mechanical property, as it is actually a function of several other mechanical properties such as elastic modulus, yield strength, and tensile strength, which all influence how far the indenter penetrates under a given load, and how much the material springs back when the indenter is removed. So, there are some other questions that would need to be addressed.

Question: How useful is hardness testing

Answer: It depends. Done properly, hardness testing can be fairly reliable and repeatable. If not done properly, you will find yourself chasing variation, rejecting good parts, accepting defective parts, etc.

On the positive side:

+ Hardness correlates decently to tensile strength, with some scatter (Figure 1).
+ It is the only test one can use to test small, finished parts.
+ If hardness is tested properly and falls within specification, then the other mechanical properties are likely, although not guaranteed, to be within specification as well.
+ Hardness testing may be useful for monitoring processes. As long as the hardness stays consistent, the process is probably within specification as well.

On the negative side:

– Hardness correlates only very loosely to yield strength and ductility, with high scatter (Figure 1).
– Hardness testing has many pitfalls that can lead to inaccurate measurements. (Table 1).
– Even correctly performed hardness tests show wide variation – so it is difficult to determine whether or not the part is within specification

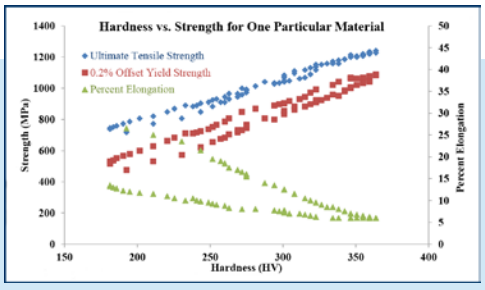

Figure 1 Hardness and Tensile Property Correlation (or Lack Thereof).
Tensile strength and hardness correlate fairly well. There is more spread in yield strength, and a greater amount of spread in ductility (percent elongation.) This chart is for one particular material in multiple heat treat conditions, and **should not** be used as a conversion chart.

The next issue of Technical Tidbits will discuss different categories of material properties.

HARDNESS VS. **STRENGTH** (CONTINUED)

Question: Can I use hardness testing to accept/reject incoming material?

Answer: If you are testing hardness on a different scale than the one used on the material certification, then proceed with extreme caution. If you test on the same hardness scale using the same scale, load, indenter, and dwell time, and your measurement is close to the certified value, the error is probably test variation, and you can feel confident. If you screen incoming material by measuring yield or tensile strength, you will probably measure within 1% of the certified values. With hardness, who knows?

Incorrect load/indenter combination for test scale	Pre-Test Procedures
Incorrect load/indenter/scale combination for size of test piece	
Incorrect load/indenter/scale combination for hardness of test piece	
Failure to properly calibrate equipment before testing	
Inadequately fixtured test piece	
Improperly prepared metallographic mount of small test piece	
Inadequate spacing between indentations	Test Procedures
Inadequate number of measurements	
Conducting test on the wrong surface/area of part	
Conducting test through plating or other surface coating	
Failure to account for effect of rough or work hardened surface	
Failure to properly correct measurements for surface curvature	Post-Test Procedures
Incorrect use of conversion charts	
Failure to account for variability of test itself	

Figure 2 Potential Pitfalls of Hardness Testing.

The first 13 are all procedural errors that can be avoided by following standard operating procedures and using common sense. The last item is the source of most heartaches, as different machines, different labs, and different operators may come up with wildly different hardness measurements, and the raw material itself may have a number of constituent phases that have different hardness value, which can have a large effect on the overall measured value, particularly on microindentation tests.

Question: Can I use hardness to judge if material has been properly heat treated?

Answer: You may if you follow the specifications and guidelines, and test appropriately.

In summary, there are many caveats to using hardness testing to evaluate material condition. Hardness tests measure hardness only, and it is risky to infer other material properties from the result of the test. However, there are circumstances where hardness testing is the only possible measurement that you can make to evaluate materials. You will need to exercise good engineering judgement in deciding whether or not your parts meet your specifications when hardness is the only property you can measure. In this case, it is best used as a means of statistical process control, to see when and if the process drifts.

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References:

Technical Tidbits Issue No. 25 – "Hardness Testing."

Technical Tidbits Issue No. 26 – "Hardness Testing Pitfalls."

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