WALLCOLMONOY
SURFACING ALLOYS

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The Importance of Hardness Testing for Hardsurfacing

Hardness testing provides an excellent quality tool to ensure that the coating or weld overlay process achieves the desired output. Obtaining accurate readings through testing techniques and good practices can reveal issues proactively and prevent parts from being scrapped.

Hardness is defined as the resistance of a metal to permanent indentation under a static load or to scratching. Hardness testers are designed to apply a load via an indenter to the material being tested under controlled conditions. When a hardness tester uses a load greater than 1 kg the test is considered a "macro hardness test". When the load is less than 1 kg, it is considered a "micro hardness" test.

The most commonly used hardness testers for hardsurfacing applications are the Rockwell Hardness test and the Vickers Hardness test. The Rockwell instrument can use test loads ranging from 15 kg to 150 kg force and measures a macrohardness. The Standard Test Method for Rockwell Hardness of Metallic Materials ASTM E18 provides the basis for equipment and operation. Vickers hardness can be either macro or micro depending on the instrument. ASTM E92 covers Vickers macro test loads of 1 kg to 120 kg force. ASTM E384 covers micro test loads from 25 g to 1000 g force.

The Rockwell tester uses the depth of indentation to calculate a hardness number. The Vickers tester requires that the diagonals of the indentation made by a square based diamond indenter be measured and the average used to calculate the hardness number. Larger loads create a larger indentation which encompass more grain boundaries and phases where multiple phases are present. Figure 1 illustrates this.

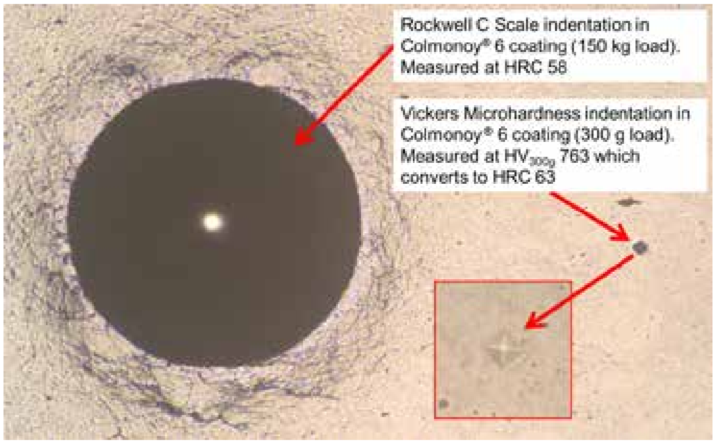

Figure 1. A comparison of Rockwell C and Vickers 300g hardness indentations on a Colmonoy® 6 spray & fuse deposit.

By selecting a load that gives an appropriate size indentation the microhardness test can be used to identify hardness of phases within a coating. For example, the image below shows HV100g indentations on a cross section of spherical tungsten carbides contained in a Plasma Transferred Arc Weld deposit. The size of the carbides is about 75 micron and smaller.

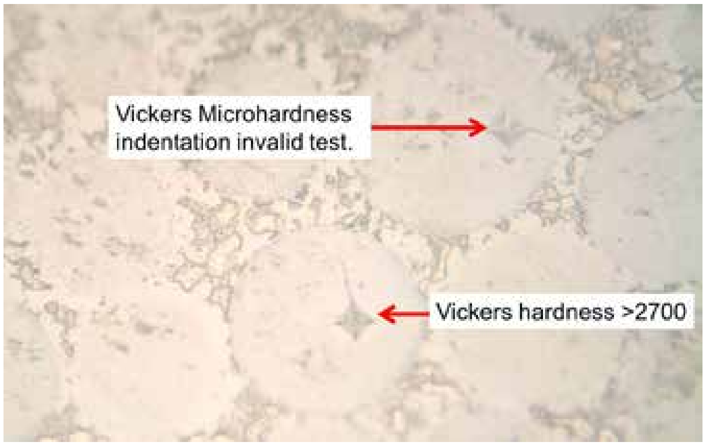

Figure 2. Vickers microhardness test used to test hardness of spherical tungsten carbide in a Colmonoy® 5002 deposit.

Hardness readings are typically employed to compare one material to another especially where materials are used for hardsurfacing applications. One hardness scale that may have been taught in your

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school is the Mohs hardness scale. This hardness scale is particularly interesting from the surface engineering point of view in that hardsurfacing applications are often designed to prevent or minimize wear by one or more of the Mohs hardness minerals (sand – quartz) or combinations thereof (granite – quartz, feldspar, mica).

Mohs Hardness Scale	Common Reference Materials	Vickers Hardness	Rockwell C Hardness
10 Diamond		8000	-
9 Corundum	9.1 Tungsten carbides WC/W_2C	2085	-
8 Topaz	8.5 Masonry drill (cemented carbide)	1648	~78
7 Quartz (silica sand)		1260	~72
6 Orthoclase (feldspar)	6.6 Colmonoy® 88 6.5 Steel nail	714	~61
5 Apatite	5.5 Knife blade / Glass plate	659	~58
4 Fluorite		200	<20
3 Calcite	3.5 Copper penny	145	-
2 Gypsum	2.5 Fingernail	60	-
1 Talc		47	-

The Rockwell and Vickers hardness testers referred to are free standing or bench top instruments which rely on a suitably sized sample to be prepared and brought to the instrument. Often testing is needed on an actual part rather than a sample and the part may be too large to fit into one of the standard testers. Various portable testers are available that provide hardness results which can be correlated to Rockwell or Vickers or other hardness scales. These portable testers include but are not limited to instruments that use:

- Dynamic Rebound Methods
- Ultrasonic Contact Impedance Methods
- Indentation Methods

When using a non-standard portable tester, it is important that all parties involved understand the method and its' applicability for use as acceptance criteria or for other decision making activities.

Hardness Testing of Self Fluxing Spray & Fuse Alloys

For hardsurfacing alloys, like Colmonoy® (nickel-based) and Wallex® (cobalt-based), the hardness test is one of the most useful measurements (along with various wear testing) that can be made. It is important to select the correct alloy powder with the appropriate particle size distribution for the service conditions and application equipment. In order to obtain meaningful and reliable hardness values, the test must be done properly and with a full understanding of the variables and effects.

This article will be confined to the indentation type of hardness testing on spray & fuse deposits as performed with a Rockwell type of macrohardness tester. Brinell indentation type tests and energy adsorption type tests such as Shore Scleroscope are not strictly suitable. Microhardness tests such as Vickers or Knoop require additional sample preparation steps but are valid methods.

Testing of hardness on spray & fuse deposits differ in many respects from hardness testing of homogeneous wrought metals such as steel, aluminum, copper, etc. The heterogeneous microstructure of spray & fuse deposits is composed of solid solution, eutectic and intermetallic compounds (typically hard carbide, boride, and silicide phases). As with any material the microstructure can contain inclusions or porosity. Spray & fuse deposits may contain borosilicate slag as a result of the fluxing action that takes place during fusing. In addition, if the deposit is very thick, there may be porosity and shrink cavities that influence hardness values.

It is obvious that a single point indentation, such as the Rockwell diamond spheroconical indenter, indicates the hardness over the entire contact area and generally not the hardness of any single microconstituent. In spite of these heterogeneous microstructures, very uniform and meaningful indentation hardness values can be obtained with proper procedures.

Obtaining Accurate Readings Through Testing Techniques and Good Practices

The following points must be considered when determining hardness on spray & fuse deposits:

1. For accurate hardness readings, it is important to use a full size machine designed to meet relevant ASTM criteria. It must be in good condition and verified with standard test blocks.

2. Portable hardness testers can be used as long as all concerned parties agree.

3. Test specimens must be properly prepared. The test surface and the bottom surface should be ground and as close to flat and parallel as possible. The test surface and the bottom surface should be smooth, even, and free from oxide scale, foreign matter, and lubricants. It is generally agreed that a smoother test surface produces better repeatability. As an example, Standardized Rockwell test blocks must have a mean surface roughness of Ra ≤ 0.003 mm (12 µin) (both test and bottom surfaces).

4. The operator should be well trained in the test procedure and verification requirements.

When it is realized that a movement of 0.0254 mm (0.001") of the test piece can result in an error of 12.7 Rockwell hardness units, we can appreciate that hardness testing is indeed a precision operation.

Careful testing technique will give accurate readings. Most erroneous readings are low and may be caused by the following reasons:

a. Deposit thickness - Since the base metal is nearly always softer than the deposit, adequate deposit thickness is necessary to support the load on the diamond indenter. The minimum deposit thickness required varies with the hardness and the load on the diamond. The following table can be used as a guide since the base metal does not have the same hardness as the tester support (anvil).

b. Convex Cylindrical Surfaces - A correction factor must be added to the observed value when checking convex surfaces. The correction factors are available from equipment manufacturers and are given in ASTM E18.

c. Slag Inclusions - A quality spray & fuse deposit may contain borosilicate or oxide micro-inclusions. The effect of these inclusions is to lower the apparent hardness. However, hardness readings will be uniform. When due to poor spraying practice, these inclusions are very large, hardness readings will become very erratic and indicate a potential quality problem.

d. Porosity - Everything that has been said about slag inclusions also applies to porosity. Porosity has an even greater effect than slag inclusions in lowering the hardness readings.

e. Deposits Made on a Flat Specimen - When a hardness test specimen is made by spraying on a flat block of steel, the liquidus is sometimes exceeded during fusing since the deposit does not sag or run as it would on a cylindrical specimen. Exceeding the liquidus temperature causes the deposit to behave more like a casting. Shrinkage cavities and coarse dendritic structure in the central area that freezes last during solidification. Hardness tests made in the central area of such a deposit will always be low because of the underlying structure. Avoid overheating during fusing of deposits on flat surfaces.

f. Hardness Testing Procedure - **Good practices**

   a. After changing indenter or anvil make two indentations to ensure proper seating of these parts.

   b. Take at least 5 hardness readings in a representative area. Average the 5 remaining readings and report hardness to the nearest whole number.

Minimum Thickness		**Rockwell C Scale (150 kg_f)**	**Rockwell C Scale (60 kg_f)**
Millimeter	**Inch**		
0.36	0.014	No valid test	No valid test
0.41	0.016		86
0.46	0.018		84
0.51	0.020		82
0.56	0.022	69	79
0.61	0.024	67	76
0.66	0.026	65	71
0.71	0.028	62	67
0.76	0.030	57	60
0.81	0.032	52	
0.86	0.034	45	No valid test
0.91	0.036	37	
0.96	0.038	28	
1.02	0.040	20	

Conclusion

Hardness testing is a quantitative test. With proper technique, understanding and equipment, the values can be meaningful and reliable - reviewing issues proactively and preventing scrapped parts. It should be used to establish confidence in the selection, application, and quality of spray & fused hardsurfacing deposits.

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About Wall Colmonoy

For over 80 years, Wall Colmonoy is a global leader in the manufacture and application of Colmonoy® (nickel-based) and Wallex® (cobalt-based) surfacing powders.

Wall Colmonoy's standard and custom range of Colmonoy® and Wallex® surfacing alloys have outstanding metallurgical and physical properties making them ideally suited to solving engineering problems such as Wear, Corrosion, Erosion and Abrasion.

Our specially formulated Colmonoy® and Wallex® alloys extend the useful life of engineered components for such global industries as Oil & Gas, Glass Container, Rubber & Plastics, Power Generation, Energy and Steel.

Available as powder, rods and wire in a full range of sizes and specifications. Supplied in a range of proven surfacing and thermal spraying techniques including Laser Cladding, PTA, HVOF, Sprayweld™ and Fuseweld™.

Known for our unique proven way of creating superior performing alloys that extend the useful life of engineered components, we pride ourselves on long-term strategic customer collaboration that produces value-added ideas and creative solutions.

Our manufacturing facilities in North America and United Kingdom are equipped with the latest modern laboratory, testing, research & development facilities. Our products are manufactured to quality standards set by international and national industrial associations. We maintain the quality assurance of ISO 9001.

Wall Colmonoy. 80 Years of Making Metals Work Harder.

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