Krautkramer
An AGFA Agfa Company

Portable Hardness Testing

- Application Guide -

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1. Introduction

Mobile hardness testing is on the advance: In these times of cost pressures and higher quality requirements there is a quick and economical supplement to stationary hardness testing in the modern production process. The application possibilities are far ranging, this includes large as well as small parts, and especially applies to positions which are difficult to access.
There are two different physical methods which are particularly recognized in the practical field: the static UCI method and dynamic rebound hardness testing. The decision as to which method is used mainly depends on the test task.

Fig. 1: Hardness testing with a UCI instrument on the tooth flanks of a pinion shaft.

Fig. 2: Hardness testing with a rebound tester on the drive wheel of a large hydraulic digger.

Krautkramer offers two series of portable hardness testers, one operating on the UCI Ultrasonic Contact Impedance principle (MIC 10) and the other on the rebound principle (DynaMIC and DynaPOCKET).

This paper explains the basic principles of both test methods and compares, using examples from the practical field (e.g. hardness testing in the heat affected zone of welds), the application possibilities of both methods. In addition to this, the subjects critically discussed are the factors of influence on hardness testing, such as surface preparation or the wall thickness of parts to be tested, e.g. pipelines.

1.1 What is hardness?

With regards to metals, hardness has always been a subject of much discussion among technical people, resulting in a wide range of definitions. Hardness properties include such varied attributes as resistance to abrasives, resistance to plastic deformation, high modulus of elasticity, high yield point, high strength, absence of elastic damping, brittleness or lack of ductility.
To a metallurgist, hardness is a material's resistance to penetration. In general, an indenter is pressed into the surface of the material to be tested under a specific load for a definite time interval, and a measurement is made of the size or depth of the indentation
Hardness is not a fundamental property of a material, but a response to a particular test method. Basically hardness values are arbitrary, and there are no absolute standards for hardness. Hardness has no quantitative value, except in terms of a given load applied in a specific, reproducible manner and with a specified indentor shape.
Static indentation tests in which a ball, cone or pyramid penetrates into the surface of the material being tested are widespread. The relationship of load to the area or depth of indentation is the measure of hardness, such as in common bench-top Brinell, Rockwell, Vickers or Knoop hardness testers.
The different methods and differently shaped indenters used by e.g. Brinell and Rockwell produce dissimilar responses of the material under test. Tables relating to HRC and HB values are only approximations – there exists no mathematical equation to transfer measurements from one scale to another. So-called conversion tables have to be determined empirically by experimental evaluation of a specific material's hardness with the different test methods. To compare the hardness of two different samples, both must be measured using the same hardness scale, or a scale must be developed to convert from one measurement to the other. Hardness scales are only in relationship to themselves!

1.2 Why hardness testing?

In manufacturing applications, materials are primarily tested for two reasons: either to research the characteristics of a new material or as a quality check to ensure that the sample meets a particular specification.

1.3 On-site hardness testing?

Conventional hardness testers such as Rockwell, Brinell or Vickers machines require the test piece be brought to the testing device; but this is not always possible. Portable testing devices have been developed that permit in-situ hardness measurements.
One popular device measures the frequency shift of a resonating rod with a Vickers-diamond tip, which occurs when the diamond penetrates into the test material by applying a specific test load. The frequency shift is evaluated and electronically converted to hardness value displayed on the LCD. The MICRODUR 10 instrument (Krautkramer) works according this method, the so called UCI (Ultrasonic Contact Impedance) method.
Another well-known principle for portable hardness testers is the rebound method. The DynaMIC or DynaPOCKET (Krautkramer), for example, measures the velocity of a propelled impact body directly before and after the impact onto the test material's surface. The ratio between both velocities indicates the hardness of the material, which can be converted into different scales by using conversion tables stored in the instrument for different materials.

2. The UCI Method (MIC 10)

As in standard Vickers or Brinell hardness testing, the question as to the size of the test indentation in the material generated by a certain test load also arises in Vickers hardness testing according to the UCI (Ultrasonic Contact Impedance) method. However, the diagonals of the test indentation, which have to be known in order to determine the Vickers Hardness value, are not evaluated optically as usual, but the indentation area is electronically detected by measuring the shift of an ultrasonic frequency. This can be illustrated by a small imaginary experiment.
A UCI probe typically consists of a Vickers diamond attached to the end of a metal rod (Fig. 3). This rod is excited into longitudinal oscillation at about 70 kHz by piezoelectric transducers. Imagine instead of the metal rod (we refer to it as oscillation rod) a large spiral spring held at the end and oscillating at a resonant frequency of 70 kHz at the free end (Fig. 4).
At the very top of this spring (free end) there is a contact plate, the Vickers diamond. The test material, with which the Vickers diamond comes into contact, can also be imagined as being a system of smaller spiral springs positioned vertically to the surface - an atomic bonding, two atoms inter-linked via a "spring". If only one of these "atomic springs" is touched by the Vickers diamond in this imaginary experiment - like very hard material in which the diamond only slightly penetrates and thus produces a small indentation – then an additional spring, i.e. mass, is coupled to the large spiral spring. By doing this, the resonant frequency shifts due to this additional mass / spring.

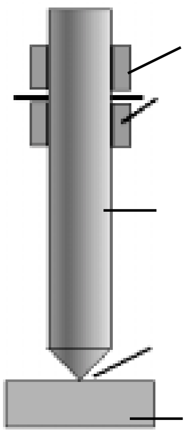

Fig 3: Schematic description of the UCI probe

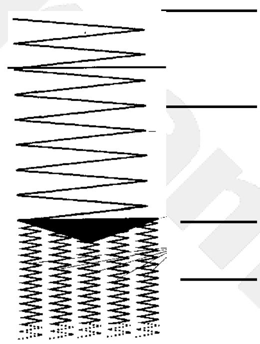

Fig 4. UCI principle in an imaginary experiment: an oscillating spring in contact with material. The spring symbolizes the oscillating rod, the contact plate symbolizes the diamond, the material springs symbolize the material and its elastic constants.

This frequency shift will become greater when additional "springs" are touched, that means if the diamond penetrates deeper into a material of medium hardness, and the test indentation becomes larger. Analogously, the largest frequency shift is produced by soft test materials; the diamond penetrates deeper into the material and leaves a large indentation.
This is the secret of UCI hardness testing: the frequency shift is proportional to the size of the test indentation produced by the Vickers diamond. Equation (1) describes this basic relation in comparison to the definition of the Vickers hardness value.

$$\Delta f \approx E_{elast} \cdot \sqrt{A} \qquad HV = {}^{F}\!/_{A} \tag{1}$$

Equation 1: The Frequency shift is proportional to the indentation size of a Vickers indentor. Δf = frequency shift, A = area of indentation, E_{elast} = Young's modulus, HV = Vickers hardness value, and F= Force applied in the Vickers hardness test.

The frequency shift nevertheless also depends on the Young's modulus of elasticity, which is a material constant such as the spring constant in our mental experiment. For the practical application of the UCI-method the Young's modulus, therefore, has to be considered. The instrument has to be calibrated when the hardness of different materials with different values of the Young's modulus has to be determined.

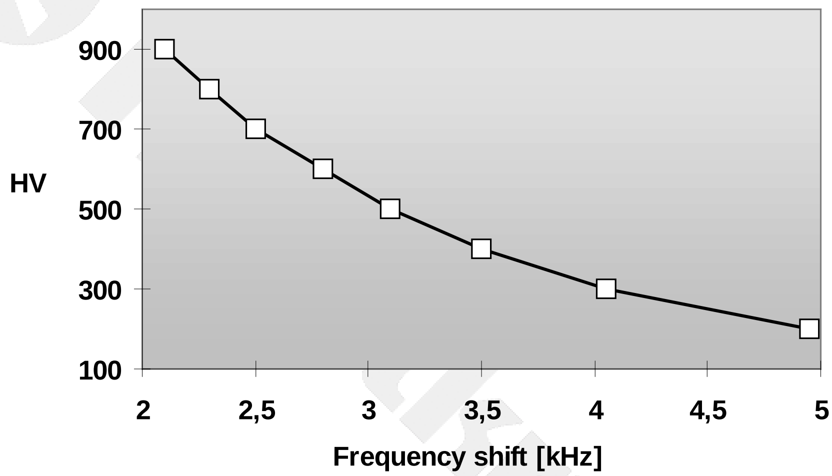

Fig 5: Vickers Hardness value versus frequency shift of the oscillating rod.

After completing the calibration, the UCI method can be used for all materials showing this modulus of elasticity. When being manufactured, the probes are calibrated on low-alloyed or unalloyed steels; however, modern test instruments can be calibrated quickly, also at the test location, to other materials as well, such as titanium or copper.

2.1 Selecting the MIC probe

To carry out the UCI principle, a probe containing a rod with a Vickers diamond attached to the contact end is resonated by piezoelectric ceramics at an ultrasonic frequency.
A spring applies the load and the frequency of the rod changes in proportion to the contact area of the indentation produced by the Vickers diamond. Therefore the hardness value is not visually determined by the diagonals of the indent, as would normally be the case with a workbench hardness tester, but by an electronic measurement of the frequency shift within seconds.
The instrument constantly monitors the frequency, performs the calculation and instantaneously displays the hardness value.
The UCI method is best suited for testing homogeneous materials. Five different loads are employed by the various models of UCI probes.

Load	Available Models	Advantage or Benefit	Typical Applications
98 N	MIC-2010 Standard Length Handheld Style	Largest indentation; requires minimal surface preparation	Small forgings, weld testing, HAZ
50 N	MIC-205 Standard Length Handheld Style	Solves most general applications	Induction or carburized machined parts, e.g. camshafts, turbines, weld inspection, HAZ.
	MIC-205L Extended Length Handheld Style	30mm extended length	Measurement in grooves, gear tooth flanks and roots
	MIC 205S Short Probe Handheld Style	Reduced length, 90 mm, electronics in separate housing	Turbine blades, inside tubes with ∅ > 90mm
10 N	MIC-201 Standard Length Handheld Style	Load is easy to apply; provides control to test on a sharp radius	Ion-nitrided stamping dies and molds, forms, presses, thin walled parts
	MIC-201L Extended Length Handheld Style	Measurement on complicated geometries	Bearings, tooth flanks
	MIC 201S Short Probe Handheld Style	Reduced length, 90 mm, electronics in separate housing	Turbine blades, inside tubes with ∅ > 90 mm
8 N	MIC-211 Motor Probe Style	Use with urethane fixtures for complex shapes	Finished precision parts, gears, bearing raceways
3 N	MIC-2103 Motor Probe Style	Shallowest indentation	Layers, e.g. copper or chromium layers on steel cylinders (≥ 40 µm), Copper Rotogravure cylinders, Coatings, Hardened layers (≥ 20 µm)

Table 1 UCI (MIC 10) probe models, their benefits and typical applications.

3. The Rebound method
(DynaMIC and DynaPOCKET Hardness Testing according ASTM A 956-00)

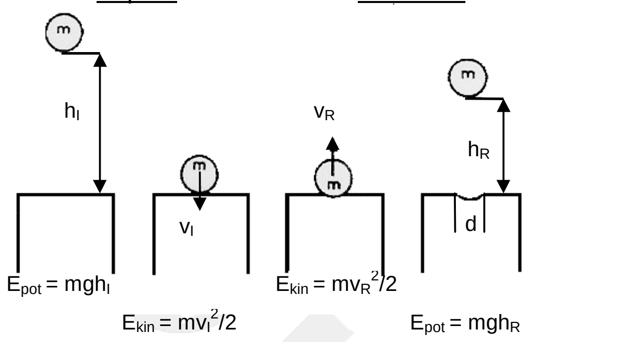

Fig. 6: The basic principle of the rebound hardness test d= diameter of indentation, E_{pot}= potential energy, E_{kin}= kinetic energy.

Hardness testers using Leeb's method operate in a slightly different manner. Although the size of the test indentation generated is connected with the material hardness even in this case, it is indirectly measured via the loss of energy of a so-called impact body. Fig. 6 illustrates the physical principle of measurement. A mass is accelerated to the surface of the test object and impinges on it at a defined speed, i.e. kinetic energy. The impact creates a plastic deformation of the surface, i.e. an indentation, due to which the impact body loses part of its original speed - or energy. It will lose more speed by creating a bigger indentation and, thus, at softer material. Technically, this principle of measurement is implemented by means of an impact body which has a spherical tungsten carbide tip and which is accelerated onto the test surface by spring force.

The velocities after and before the impact are each measured in a non-contact mode. This is done by a small permanent magnet within the impact body (Fig. 7) which generates an induction voltage during its passage through a coil, with this voltage being proportional to the speed (Fig. 8).

The inventor of this method, D. Leeb, defined his own hardness value, the Leeb hardness value. The Leeb hardness value, HL, is calculated from the ratio of the impact and rebound speed according to:

$$HL = \frac{v_R}{v_I} \cdot 1000 \qquad (2)$$

v_I, v_R = speed before / after the impact

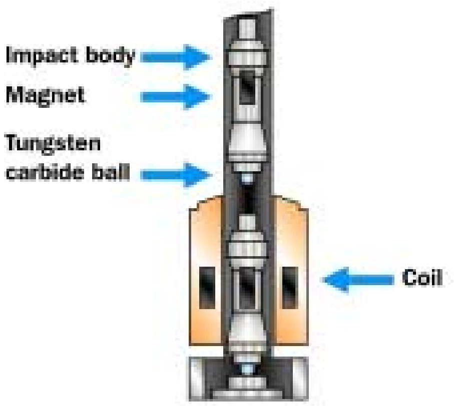

Fig. 7: Cross-cut of a typical impact device

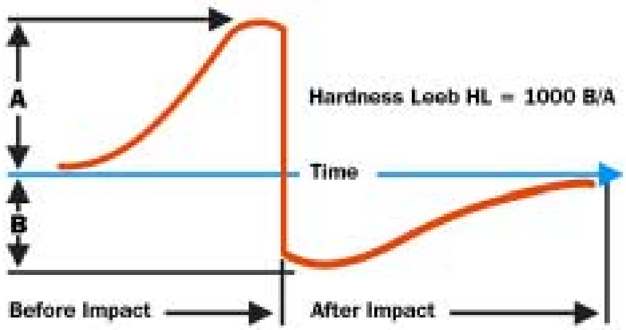

Fig. 8: Voltage signal generated by the impact body traveling through the coil. The signal is shown before and after the impact.

You might asked yourself: "Who wants to measure the hardness value in Leeb?". The answer is: as a matter of fact, anybody who uses the rebound hardness testing method does it because the Leeb hardness value is, by definition in the equation (2), the actual physical measurement value behind this method. However, nearly no user indicates the Leeb hardness value HL in his specifications or test reports. We mostly convert into the required hardness scales (HV, HB, HS, HRC, HRB, N/mm^2). For this reason, only conversion brings the rebound hardness method to life. Therefore, conversion tables, like in Fig. 9, are stored in all instruments.

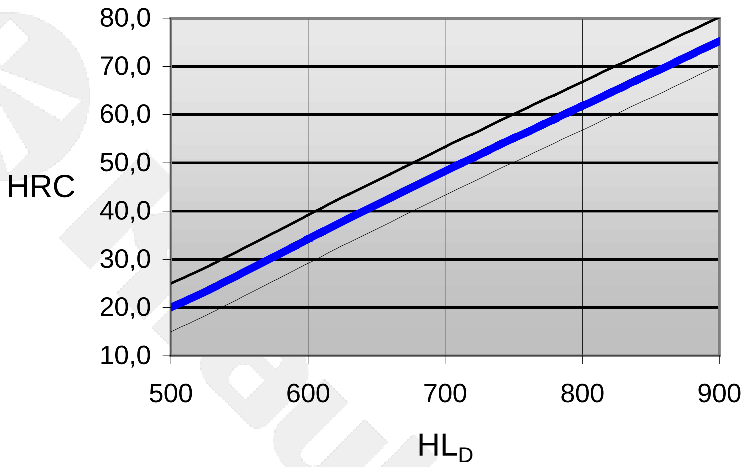

Fig. 9: Conversion of Hardness Leeb, HL, into HRC as a typical example for conversion tables stored in rebound hardness testers. These curves are experimentally generated by material samples of different hardness measured by rebound and Rockwell tests.

The series of rebound hardness testers includes the DynaMIC and DynaMIC DL instruments and three models of interchangeable impact devices as well as the compact DynaPOCKET hardness tester.
To apply the principle, an impact device uses a spring to propel an impact body through a guide tube towards the test piece. As it travels towards the test piece, a magnet contained within the impact body generates a signal in a coil encircling the guide tube. After the impact, it rebounds from the surface inducing a second signal into the coil. The Krautkramer instrument calculates the hardness value using the ratio of the voltages and analyzes their phases to automatically compensate for changes in orientation. Due to the patented signal processing there is no need for any manual correction for the impact direction. The Krautkramer hardness tester DynaMIC and DynaPOCKET offer this autobalancing feature.
Application solutions are determined by the force and indenter of the impact body. The operator can select from three models of impact devices for the DynaMIC (Dyna D, Dyna E and Dyna G) as well as the DynaPOCKET.

Model	Indenter	Impact Energy	Typical Applications
Dyna D	3 mm Tungsten Carbide Ball	12 Nmm	General purpose testing of homogeneous material
Dyna E	3 mm Diamond	12 Nmm	>50 HRC, e.g. forged and hardened steel mill rolls
Dyna G	5 mm Tungsten Carbide Ball	90 Nmm	<650 HB, e.g. Large castings and forgings, lower surface requirements (n9 as opposed to n7 with Dyna D)
DynaPOCKET	3 mm Tungsten Carbide Ball	12 Nmm	Compact, integrated rebound hardness tester

Table 2: DynaPOCKET and DynaMIC Series Impact Devices, their benefits and typical applications.

4. Application

4.1 Selecting the method

The UCI method is recommended for testing fine grained material having any shape and size. It is especially used where material properties are to be processed with narrow tolerances, e.g. for determination of strain hardening on drop forged parts. Rebound hardness testing is carried out on large, coarse grained materials, forged parts and all types of casted materials because the spherical tip of the impact device produces a rather larger indent than the Vickers diamond and therefore processes the characteristics of the casting structure better. With the small indent of the Microdur UCI probes, determination of the hardness can be made on welded parts in the critical area of the weld, the heat affected zone (HAZ). A number of probes and impact devices having different test loads open up different areas of application.

Application	UCI testing	Rebound testing
Solid parts	**+**	**++**
Coarse grain materials	**-**	**++**
Steel and aluminum casted alloys	**o**	**++**
HAZ with welds	**++**	**-**
Tubes: wall thicknesses > 20 mm	**++**	**++**
Tubes: wall thicknesses < 20 mm	**++**	**-**
Inhomogeneous surfaces	**-**	**+**
Thin layers	**++**	**-**
Difficult to access positions	**++**	**+**

(++ especially suited / + well suited / o suited sometimes / - not recommended)

Table 3: Applications for UCI and rebound hardness testing.

For rebound hardness testing, impact devices are offered with different test loads. In addition to the impact device Dyna D, which covers standard applications, there is the impact device Dyna G, having an impact energy which is nine times higher and has a larger tungsten carbide tip, designed for testing solid casted or forged parts; the impact device Dyna E is recommended for parts above a hardness of 650 HV/56 HRC and has a diamond tip instead of a tungsten carbide tip.

4.2 Indentation size

In general, the larger the area sampled by an indentation the more consistent the test results. The variations in microstructure of non-homogeneous materials or those comprised of large coarse grains are averaged out and consistent hardness values can be achieved. Also a larger indentation puts fewer demands on the surface finish and requires less surface preparation.

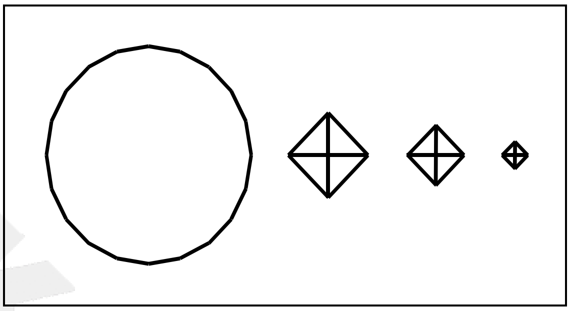

Fig. 10: Comparison of indentation width for Dyna D impact device and MIC 2010, MIC 205, MIC 201probe

In comparison, the indentations yielded by the various impact devices of rebound testers are much larger than those created by any UCI probe. When testing large castings and forgings the rebound tester is recommended. Testing small homogenous materials that are surface hardened require the shallower indentations produced by UCI probes. Table 4 a + b are provided to compare the indentation size of rebound impact devices and UCI probes at three levels of hardness.

	Dyna G 5 mm ball, 90 N mm	Dyna D 3 mm ball 12 N mm	MIC 2010 98 N	MIC 205 50 N	MIC 201 10 N	MIC 2103 3 N
64 HRC		350	152	107	48	25
55 HRC	898	449	175	124	56	28
30 HRC	1030	541	249	175	79	41

Table 4a: Approximate indentation width (in µm) at different hardness levels.

	Dyna G 5 mm ball, 90 N mm	Dyna D 3 mm ball 12 N mm	MIC 2010 98 N	MIC 205 50 N	MIC 201 10 N	MIC 2103 3 N
800 HV		16	22	16	7	4
600 HV	63	28	25	20	9	5
300 HV	83	35	35	25	11	6

Table 4b: Approximate indentation depth (in µm) at different hardness levels.

Relation of Penetration Depth and Minimum Thickness for Coatings

For Vickers hardness testing, the thickness or depth of hardened layer or coating like chromium on steel rolls must be substantial enough to support the indentation. As a rule, the thickness should be a minimum of ten times the indentation depth.

You can easily calculate the penetration depth of the Vickers diamond if you know the force of the probe and approximately the hardness by using equation 2. This formula is just based on geometry of the Vickers diamond. Therefore, the equation is only valid for a Vickers test.
(Remember: Newton, 10 N ≈ 1 kgf.)

Penetration depth	$d\ [\mathrm{mm}] = 0.062 \cdot \sqrt{\frac{\text{Test Load [N]}}{\text{Vickers Hardness [HV]}}}$
Minimum thickness	$s = 10 \cdot d$

Equation 2: Penetration depth of a Vickers diamond

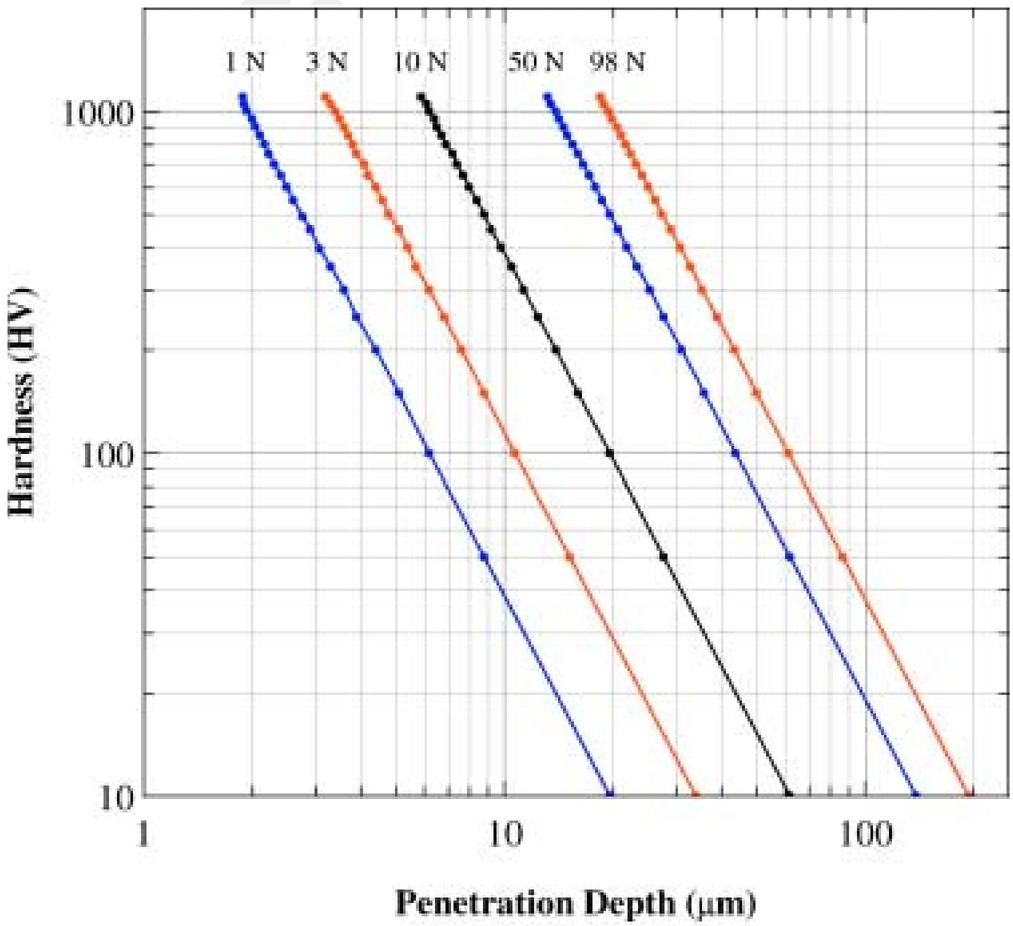

Fig. 11: Penetration depth of the Vickers-Diamond vs. the hardness for different test loads

Hardness Testing at HAZ

Hardness testing on welded parts is another excellent example of showing the importance of the indentation size. Hardness measurements , especially in the HAZ determine whether the welding was done properly or not. For example, high martensite content in the HAZ very often causes cracks at the weld. A high hardness peak in the HAZ, therefore, gives a good indication about the material's condition.
Of course, only those techniques can be used which just measure in this small critical area of about 0.2 to 0.3 mm. Using Brinell or even the Telebrineller (which is still very often used to check welds on pipes etc.) results in quite large indentation sizes. Obviously, those measurements will give just an average and, therefore, a lower hardness value than the "real hardness" of the HAZ, due to the overlapping measurement zone with zones of lower hardness. This may lead to the conclusion that no further heat treatment of the weld will be necessary. Whether this was a wise decision or not must be left to the opinion of the reader.
It clearly comes out that just Vickers hardness testing with low loads (HV5 or HV10) results in indentation sizes which are located within the small critical area.

Fig. 12: Hardness Testing at a heat affected zone (HAZ)

4.3 Test piece mass requirements

Consideration must be given to the mass of the test piece. Although the requirement for the Leeb method is much greater than that for the UCI method, both methods can be influenced by the weight and thickness of the test piece.
The Leeb method creates a large force of short duration during the impact. Thin and lightweight materials flex causing erroneous values. A solution for testing small simple shaped components is a machined support that matches the contour of the back surface of the part. The support reinforces the part to make it ridged. Extremely thin materials may also require the use of a light grease or paste to couple the part to the support.
The UCI method is based on measuring a frequency shift. Parts less than about 0.3 kg can go into self-oscillation causing erroneous or erratic readings. The support plate and coupling technique described above is also an effective method to make small components non-resonating. If the use of a support plate is not feasible, select a probe with a lower load to reduce the effects of self oscillation.
Table 5 is provided as a guideline for determining support requirements. How precisely the support matches the contour of the part determines its effectiveness.

	Dyna D & E	DynaG	UCI Probes
No support required	> 5 Kg	> 15 Kg	> 0.3 Kg
Requires Support	2 to 5 Kg	5 to 15 Kg	0.1 to 0.3 Kg
Requires Support & coupling paste	.05 to 2 Kg	.5 to 5 Kg	0.01 to 0.1 Kg

Table 5: Mass Requirements

4.4 Wall thickness requirements

Wall thickness of tubes, pipelines or valves are critical for portable hardness testing. As an example, a thin wall will start to oscillate like the skin of a drum when it's hit by the impact body in a rebound test.

The test object's minimum mass is indicated for the rebound method which should not exceed the specifications given in Table 5. But the wall thickness also plays an important part in selection of the test method. It can influence the hardness value even when the test object is solid and weighs a few tons.

Hardness testing method	Wall thickness in mm	Wall thickness in inches
Rebound	20 mm	0.79
UCI	2-3 mm	0.08 – 0.12

Table 6: Recommended minimum wall thickness. Certain geometries could stiffen the test piece allowing measurement of lower wall thickness'.

Despite the impact device's small mass and the low impact energy, there is a high force of about 900 N produced at the time of impact (as a comparison: the maximum force of a MIC UCI probe is 98 N). That is sufficient to produce vibrations, the same as the skin of a drum, with a wall thickness of under 20 mm - which can cause smaller hardness values and large amounts of scatter. In such cases, preference should be given to the UCI method.

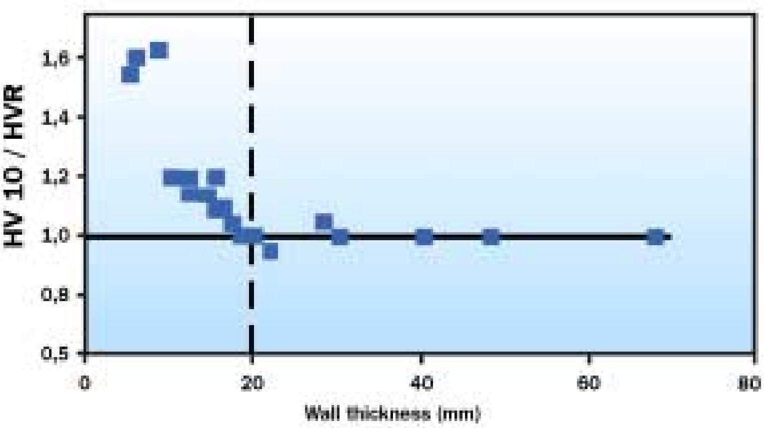

Fig. 13: Standard Vickers values (HV10) compared with Rebound values (HVR) for different wall thickness' of tubes.

Fig.13 shows the hardness values measured by a standard Vickers test with a 10 kp (98 N) force and those values measured by a Dyna D impact device.
For a wall thickness higher than 20 mm, both tests show the same results. Below 20 mm, the Vickers value measured by the rebound test is lower than the true value resulting in a deviation from the horizontal line.

4.5 Surface quality / roughness

All hardness testing methods require smooth surfaces free of oxide scale, paint, lubricants, oil, plastic coating due to corrosion protection or metal coating for better conductivity. The indentation depth should be large in comparison to the surface roughness.
If surface preparation is necessary, care must be taken not to alter the surface hardness by overheating or cold working. These values are based on values given in the specific hardness testing standards. More practical results can be achieved by using a battery driven, high speed (>12000 rpm) handheld grinder. Use 180 grid to get a smooth surface. It takes just 10 seconds.

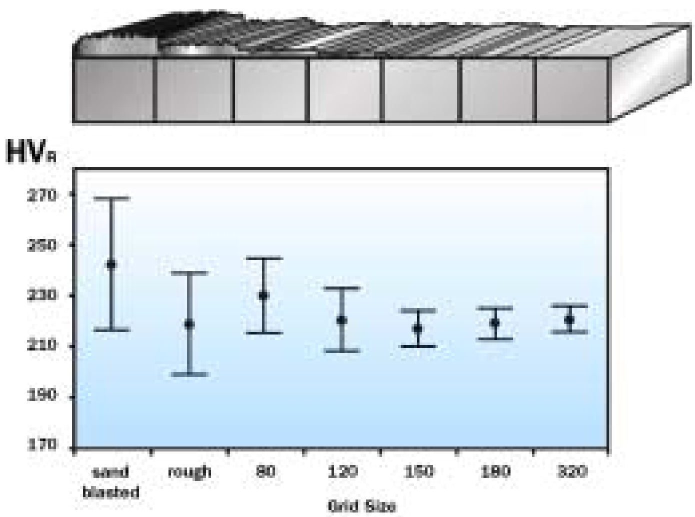

Fig. 14: Range of measured Hardness values versus surface preparation. HVR indicates converted Vickers hardness values measured by rebound hardness testing

4.6 Handling, Alignment and Fixing

Move the MIC handheld probe with slow and steady speed. The probe should be rectangular with respect to the surface. Maximum angular deviation from the straight axis should be less than 5 degrees. Avoid turning, don't drill. There should be no lateral forces on the diamond.
The DynaMIC impact device must be within two or three degrees of being perpendicular to the surface.
Support rings for the impact devices and probe shoes for the UCI probe ensure proper alignment.

The standard support rings provided with each Dyna D and Dyna E are used to test convex or concave radii greater than 30 mm. The larger diameter of the Dyna G standard support ring requires the radius to be greater than 50 mm. Support rings for the Dyna D and Dyna E impact devices are available to cover the range of r = 10-30 mm for testing the ID's or OD's of cylindrical and spherical shaped parts (see Dyna 41 and Dyna 42). Customized support rings are available on request.

For standard length UCI probes, the MIC-270 and MIC-271 probe shoes are offered as accessories. The MIC-271 is recommended for testing cylindrical parts with radii of 3-75 mm. The flat probe shoe is designed to test flat surfaces but aids in testing radii greater than 75 mm.

4.7 Calibration

Elastic modulus (or Young's Modulus) is a material property that can influence instrument calibration. Proper calibration is required to ensure the accuracy of the test results!

To calibrate the DynaMIC, the operator first must select one of nine material groups from Table 7. Selecting the appropriate material provides a rough calibration and the type of impact device connected to the instrument determines the available conversions. A more precise calibration is possible for a specific material if samples of known hardness are used to calibrate the instrument. To perform the calibration, several readings are taken on the sample and the displayed average value is adjusted to the actual "real" hardness. This establishes a precise calibration and a calibration offset value for that specific material that can be used to recalibrate the instrument.

Material Group	HV	HB	HRB	HRC	HS	N/mm^2
1 Steel – Plain, Low Alloy or Cast		D, E, G	D, E, G	D, E, G	D, E, G	D, E, G
2 Tool Steel	D, E			D, E		
3 Stainless Steel	D	D	D	D		
4 Gray Cast Iron		D, G				
5 Nodular Cast Iron		D, G				
6 Cast Aluminum		D	D			
7 Brass		D	D			
8 Bronze		D				
9 Copper		D				

Table 7: Material groups and available DynaMIC conversions

UCI probes compatible with the MIC 10 series are calibrated on steel test blocks having an elastic modulus of 210,000 MPA. Because non-alloyed or low alloyed steels have a similar elastic modulus, accurate results are obtained with the standard calibration. In many cases, the difference in elastic modulus of medium and high alloy steels is so insignificant that the error created falls within the allowable tolerances of the part.
However, the elastic modulus for non-ferrous materials require special calibrations. Several readings are taken on a test piece sample of known hardness to perform the calibration. The displayed average value is then adjusted to the actual hardness. This calibrates the instrument and also establishes a calibration offset value for that specific material that can be used to recalibrate the instrument.
Calibration offset values are referenced from a 0000 value for steel. Note that they can be either a positive or negative value. Table 8 contains a listing of approximate calibration values that can be referenced for some common materials.

Material	Calibration Offset Value
Aluminum	-8800
Chromium	+0250
Copper	-5800
Cast iron	-4800
Titanium	-6500
300 Series Stainless	-1500
400 Series Stainless	-0900

Table 8: Approximate UCI Calibration Offset Values

4.8 Verifying instrument performance

The performance of a hardness tester is verified using standardized test blocks at periodical intervals. (At this time, international hardness standards are not available and slight differences in the hardness values exist between test block manufacturers.)

The acceptable performance of the DynaMIC is based on 5 measurements on a certified Leeb test block. The average of the 5 measurements should be within ± 6 HL of the test blocks certified value. The MIC-D62 test block has a nominal value of about 765 HL. Converting to a HRC value, results in a hardness value of 55 HRC with a tolerance of ±0.5 HRC.

The accuracy of the MIC 2 and MIC 10 is based on using certified Vickers test blocks. The average of 5 readings should be within ±3.6% of the certified value of the test block when using a ridged support such as the MIC-222 test stand. When testing freehand, a minimum of 10 readings should be averaged and the tolerance is ±5%. The above tolerances have been converted to HRC values and listed in Table 9. For comparison, the required repeatability for benchtop Rockwell testers per ASTM E18 are also listed.

	MICRODUR with Fixing (3.6% of 5 readings)	MICRODUR Freehand (5.0% of 10 readings)	Rockwell Tester per ASTM E18
64 HRC	± 1.0 HRC	± 1.5 HRC	± 0.5 HRC
45 HRC	± 1.5 HRC	± 2.0 HRC	± 1.0 HRC
25 HRC	± 1.5 HRC	± 2.0 HRC	± 1.0 HRC

Table 9: UCI Probes Typical Deviation from Certified Values

5. Solution of the test task

The test task determines whether the UCI method is to be used or the rebound method of hardness testing (Table 3). It is not always immediately clear about the most suitable method. Therefore the best answer to the testing problem can mostly be given by an experienced sales engineer directly at the test location.