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Introduction

The development of technical progress in recent years leads to a constant growth of requirements for metal structures, products and components of technological equipment. This necessitates testing of properties and characteristics of used materials including quantitative assessment of materials mechanical properties. One of the most important mechanical characteristics that determine the state of a metal, strength and performance characteristics, is hardness.

Hardness measurements are widely used in industry to test products performance characteristics during manufacture and operation while relevant methods are available. Hardness testing of steels is generally performed using Brinell, Vickers and Rockwell methods. The installations that provide hardness measurement values according to the given scales are stationary machines. When testing hardness of equipment elements that are in operation, it is necessary to cut out special samples, which leads to the violation of structure integrity, which is unacceptable for most products. Therefore, portable hardness testers, **which apply Leeb dynamic method (Leeb), Portable Rockwell static method (PR) and Ultrasonic Contact Impedance method (UCI)**, are used increasingly in the current practice of metal hardness testing. The devices and measurement probes have small dimensions and can be used outside central factory laboratories directly on the surface of metallic products of power engineering facilities, transport, machine building industry, etc. Because the development of any new testing procedure implies also an introduction of new hardness scale, the given devices use conversion tables or tables and calibration characteristics received by user based on experimental data to obtain hardness values in standard Brinell, Vickers and Rockwell scales. When it is necessary to receive real hardness values according to Brinell, Vickers and Rockwell scales, it is preferable to use the stationary hardness testing machines. However, due to relatively quick and easy testing procedure, the portative hardness testers are used everywhere.

Hardness tester KT-C with the set of measurement probes presented in this booklet provides hardness testing with three most common hardness measurement methods using the portable hardness testers. User can select one of the methods in accordance with the tasks or use all three types of probes to increase accuracy and measurement reliability. The understanding of the measurement tasks, features of the tested sample and particularities of used measurement probes, which apply Leeb, PR and UCI measurement methods, will help you to choose the optimum measurement method and to define what parameters of the tested sample and working conditions shall be taken into account to receive reliable measurement results.

Features of hardness measurement methods when using portable devices

Depending on the test application, different hardness tests and probes can be used. The selection of the suitable measurement method and the probe of a portable hardness tester depends on the specific features of the given measurement task. When deciding on the use of a particular method the following is taken into account:

1. mechanical properties and material structure of the tested sample;
2. geometric parameters of the tested sample and the measurement area;
3. mass of the tested sample;
4. surface properties in the measurement area including surface roughness parameters, an existence of hardened layer, thickness of coating, etc;
5. conditions during testing and time and costs of one measurement.

The decision about the selection of the right method should be made on the basis of a complex analysis of the tested sample parameters and also on the advantages and limitations of chosen methods. The sample surface roughness and dimensions of indentation shall be also take into account to receive reliable results, because the depth of indentation shall be bigger than material microstructure. It is also necessary to consider the requirements that can be given in the normative documents for the product or allowable methods used when assessing its properties. When choosing the measurement probe, it is necessary to consider the specific features of applied testing method. The presented methods have the following advantages and limitations:

LEEB METHOD

Advantages: ease of measurements; large area of indentation decreases the influence of granularity, surface layers and surface roughness on repeatability; different types of probes allow to solve various tasks; an existence of the international standard and national primary standards makes it possible to ensure the metrological traceability according to Leeb scales (carry out the calibration in accordance with ISO 17025).

Limitations: requirements for the minimum mass and wall thickness of the tested product, requirements for the coating thickness when measuring hardness of coatings, visible imprints on smooth polished surfaces. Leeb hardness number depends on the material modulus of elasticity and has low correlation with the static hardness.

UCI METHOD

Advantages: possibility of local measurements on thin-walled products and objects with a low mass. It can be used on thin coatings. In the case of correct calibration (use of corrections for the elastic modulus) the readings are proportional to static Vickers hardness.

Limitations: requirements for the minimum mass, dimensions and wall thickness of the product, for the thickness of coatings when testing hardness of the coatings. The uncertainty of measurement results can increase on materials with high hardness.

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PR METHOD

Advantages: closest method (compared to the other portable hardness testing methods) to Rockwell method (HRA scale). The measured values are the closest to the static hardness measured by the standard methods. Use of this probe allows to apply correction for the influence of material modulus of elasticity for Leeb and UCI methods. No requirements on the mass of the tested object, the thickness of tested samples must be ten times bigger than the depth of indentation.

Limitations: relatively high time costs spent to perform tests. Impossibility to test in hard-to-reach places.

The use of the complex approach to the application of three probes provides the following advantages:

1. Higher measurement results reliability due to the results comparison obtained by different methods.

2. Possibility to avoid (minimise) the influence of stray parameters, which distort the measurement results of true (static) hardness, including the surface roughness, the influence of surface layers and also other mechanical material properties (elastic modulus) that influence readings of portable hardness testers.

3. Possibility to solve various measurement tasks including testing of coating parameters, thin-walled objects (pipes), massive complex shaped products, etc.

It is obvious from the above given information that there is no universal method that could be used for the full spectrum of hardness measurement tasks. Each method has its advantages and limitations and can be used for specific tasks. However, the complex approach to hardness testing allows to overcome the limitations of each method, obtain new possibilities to test material mechanical properties and expand the range of solved tasks and tested objects and ensure required measurement reliability.

Recommendations on probe selection to solve hardness measurement tasks

The below given sheet provides the recommendations on probe type selection for hardness testing depending on the measurement task.

	Leeb	Portable Rockwell	UCI
Oil&Gas			
Weld, Base Material & HAZ			✓
Pressure Vessels		✓	✓
Flanges	✓	✓	✓
Pipes		✓	✓
Wellhead Equipment		✓	✓
Automotie			
Engine Blocks	✓		
Shafts	✓	✓	✓
Panels		✓	
Gears	✓		✓
Brake System		✓	
Aerospace			
Turbine Blades		✓	✓
Casings/Housings		✓	
Panels		✓	
Cast Objects	✓		
Landing Gears	✓		
Manufacturing and Machinery			
Rolls	✓	✓	
Coils	✓	✓	✓
Bars/Pipes	✓		✓
Heat Treatment/Castng	✓		
Wires		✓	

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Multifunctional portable hardness tester KT-C

Purpose

Portative devices with a range of exchangeable probes designed for reliable hardness and tensile strength measurements σ of a wide range of steels (low-alloyed, high-alloyed, stainless) and cast irons and non-ferrous metals.

Hardness measurement methods

— Dynamic Leeb Method in accordance with ISO 16859.

— Ultrasonic Contac Impedance Method (UCI) in accordance with ASTM A1038, DIN 50159.

— Portable Rockwell (PR) Method in accordance with DIN 50158 (steel), ASTM B724 (non-ferrous metals).

Features

— universal device applying three hardness measurement methods;

— large number of exchangeable probes and accessories for inspection of parts of various shapes and dimensions;

— comparative measurements by various methods to improve measurement results reliability;

— measurement results conversion into standard hardness scales in accordance with ASTM E140 and ISO 18265;

— use in laboratory and manufacturing conditions;

- wide range of functions and settings: testing with tolerance limits, statistic processing of the measurement results, recording and storage of measurement results in device memory, data transfer to PC;
- 2.4” colour TFT display and built-in Li-Ion rechargeable battery;
- shock-proof ergonomic case with rubberized inserts, wear-resistant glass;
- wider range of operating temperature.

Delivery set

Electronic unit with probes (quantity and modification depends on customer's selection); charging unit; operating manual; CD with software for connection with PC and processing of the measurement results; USB cable for connection with computer; shock-proof case.

Guarantee period

electronic unit — 3 years;
probes — 2 years.

Main technical characteristics

Hardness scales		HRC, HB, HV, HRA, HRB, HSD, σ, HL
Accuracy	— for Brinell scale, HB	10
	— for Rockwell scale, HRC	1.5
	— for Vickers scale, HV	12
	— for Shore scale, HSD	2
	— tensile strength σ, %, max	5
Number of measurements to calculate average value		Up to 99
Number of stored individual calibrations		Up to 1000 (can be split into groups)
Power supply: Li-Ion rechargeable battery, V		3.7
Continuous operating time, h		12
Operating temperature range		−30...+40 °C
Overall dimensions, mm		125 × 55 × 20
Weight of electronic unit, g		120

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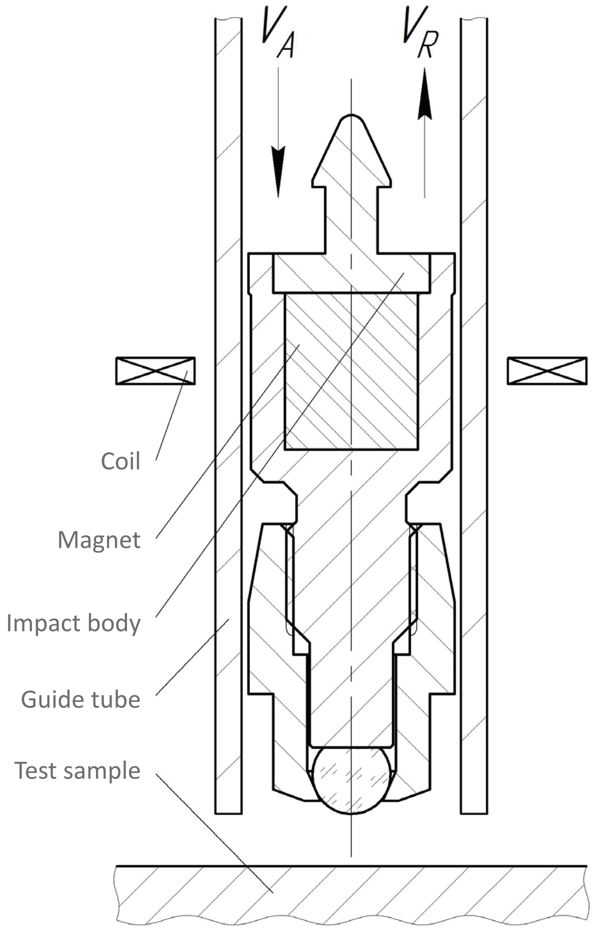
Materials, hardness scales, measurement range

Materials	Hardness scale	Hardness measurement range					
		Leeb				UCI	Portable Rockwell
		D, DC	**DL**	**G**	**C**	**U-10N U-50N U-100N**	**SPR**
Non-alloy steel, low alloy steel, cast steel	HL	0-1000	0-1000	0-1000	0-1000		
	HB	75-654	81-646	90-646	81-694	75-654	75-450
	HV	75-1000	80-950		81-1012	75-1000	75-1000
	HRC	20-70	21-67		20-70	20-70	20-70
	HRA	60-93				60-93	
	HRB	25-100	37-100	48-100		25-100	
	HSD	20-100	31-97		30-102	20-100	
	σ, MPA	370-1740	370-1740	370-1740	370-1740	370-1740	
Tool steel	HL	0-1000	0-1000	0-1000	0-1000		
	HV	80-90	80-905		98-942		
	HRC	20-70	21-67		20-67		
Stainless steel	HL	0-1000	0-1000	0-1000	0-1000		
	HB	85-655					
	HV	85-802					
	HRC	20-62					
Grey cast iron	HL	0-1000	0-1000	0-1000	0-1000		
	HB	90-664		92-326			
Nodular cast iron	HL	0-1000	0-1000	0-1000	0-1000		
	HB	95-686		127-364			
Aluminium alloys	HL	0-1000	0-1000	0-1000	0-1000		
	HB	19-165	20-187	19-168	21-167	19-165	75-450
	HV						75-1000
	HRB	24-85	24-85	28-86	23-85	24-85	
Brass (co-pper-zinc alloys)	HL	0-1000	0-1000	0-1000	0-1000		
	HB	40-173				40-173	75-450
	HV						75-1000
	HRB	14-195					
Bronze (copper-a-luminium/ copper-tin alloys	HL	0-1000	0-1000	0-1000	0-1000		
	HB	60-300				60-300	75-450
	HV						75-1000
Wrought copper alloys	HL	0-1000	0-1000	0-1000	0-1000		
	HB	45-315					75-450
	HV						75-1000

Leeb method measurement probes



Method description

When measuring hardness according to the Leeb method, the moving impact body, when falling vertically, impacts the sample surface and rebounds. The impact body velocity is measured before and after the impact. The amount of energy, absorbed or dissipated by the test sample, defines the dynamic hardness according to Leeb. It is assumed that the impact body does not deform in the measurement process.

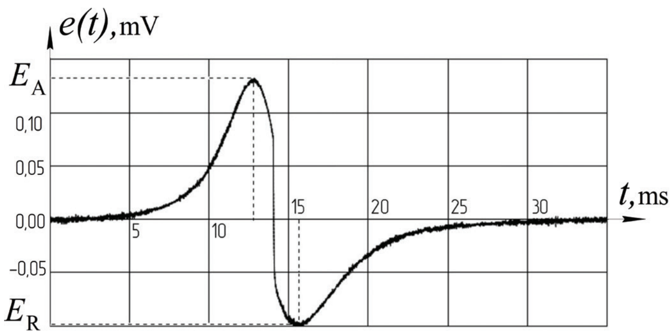
The ratio of impact velocity and rebound velocity defines the coefficient of restoration for the used configuration of the impact body and its energy. This coefficient represents a part of the initial kinetic energy returned to the impact body during the impact.

$HL = (V_R/V_A)*1000$,

where

V_R — rebound velocity of the impact body

V_A — impact velocity



A typical EMF signal as a function of time *t* induced on the coil during the measurement of hardness

The operation principle of the measurement probe

During the hardness measurement process according to Leeb method the impact body with a magnet is accelerated by a spring to velocity V_A, travels through a coil, induces EMF in the coil, which is proportional to the impact velocity. After the interaction with the tested sample, the impact body rebounds with velocity V_R and travels through the coil and induces EMF in the coil, which is proportional to the rebound velocity. On the basis of the obtained velocities values, the hardness according to the Leeb method is calculated from the expression:

$HL = (E_R/E_A)*1000$,

where

E_R – amplitude proportional to V_R

E_A – amplitude proportional to V_A

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Application

The third letter in the designation of the hardness number HLX (X = D, S, E, DL, D+15, C, G) indicates the type of used probe. The probes differ from each other in mass, impact body energy, material of the indenter (tip) and in the area of their application. The information about the specific use of probes D, DL, C and G is given in the sheet. Most often, Leeb method probes are used to test hardness of machine parts, technological equipment, pipelines, pumps, turbines, etc.

Features

The particularity of the measurement process imposes certain limitations on the scope of this method. During the Leeb method test procedure the test object thickness and mass can influence the measurement results. The falling impact body during the contact with the specimen surface transfers a part of the energy to the test specimen. In case of insufficient thickness or mass of the sample, a part of the energy can be spent on the excitation of oscillation in the sample that leads to the loss of energy and the decrease of the velocity of the rebounded impact body, which influences the measurement result.

Minimum mass and thickness values of the test piece for each type of probe are given in all valid standards for this method. In case that the sample does not meet the requirements, it is necessary to connect the tested sample to a massive base to make the measurements.

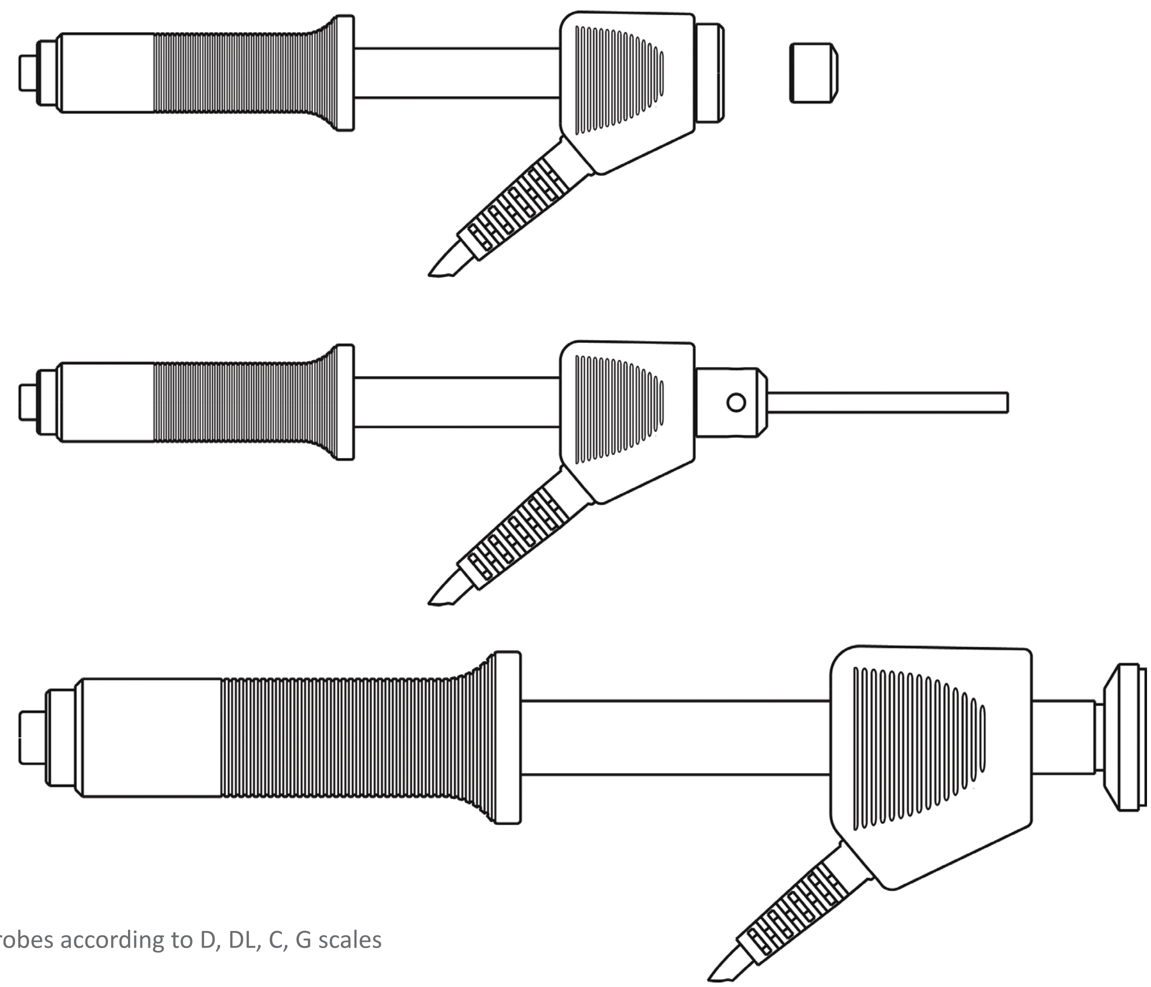
Standardisation

The Leeb hardness measurement method is standardised in the USA and Europe: DIN 50156 (1-3), ASTM A956, ISO 16859 (1-3). The standards specify the requirements and characteristics of the measurement probes (mass and energy of the impact body, radius and material of the indenter), measurement procedure, requirements for the test object, calibration of the devices, reference hardness test blocks, etc.

The measured hardness value is converted with use of the conversion tables stored in the device memory (in accordance with ASTM E140 and ISO 18265) into the required scale HB, HRC, HV and others for the selected group of metals (alloys).

Specific use of different types of Leeb scales probes

	Type D	Type C	Type DL	Type G
Purpose	Universal standard probe designed to solve the majority of the industrial hardness measurement tasks.	Designed to inspect parts with increased requirements for the indentation dimensions, parts with surface hardened layer and galvanic coatings and also thin-walled parts and products sensitive to impacts.	Designed to solve measurement tasks in hard to reach places in cramped spaces and for the inspection of the inner surfaces.	Designed to inspect massive parts with increased surface roughness, for example forged or cast parts or materials with coarse-grained structure (cast iron) and rough surface.
Minimum thickness of test sample object, mm	10	5	10	70
Maximum surface roughness, Ra, µm	3.2	1.6	3.2	12.5
Dimensions	Ø 23×139	Ø 23×139	Ø 23×255	Ø 32×248



Probes according to D, DL, C, G scales

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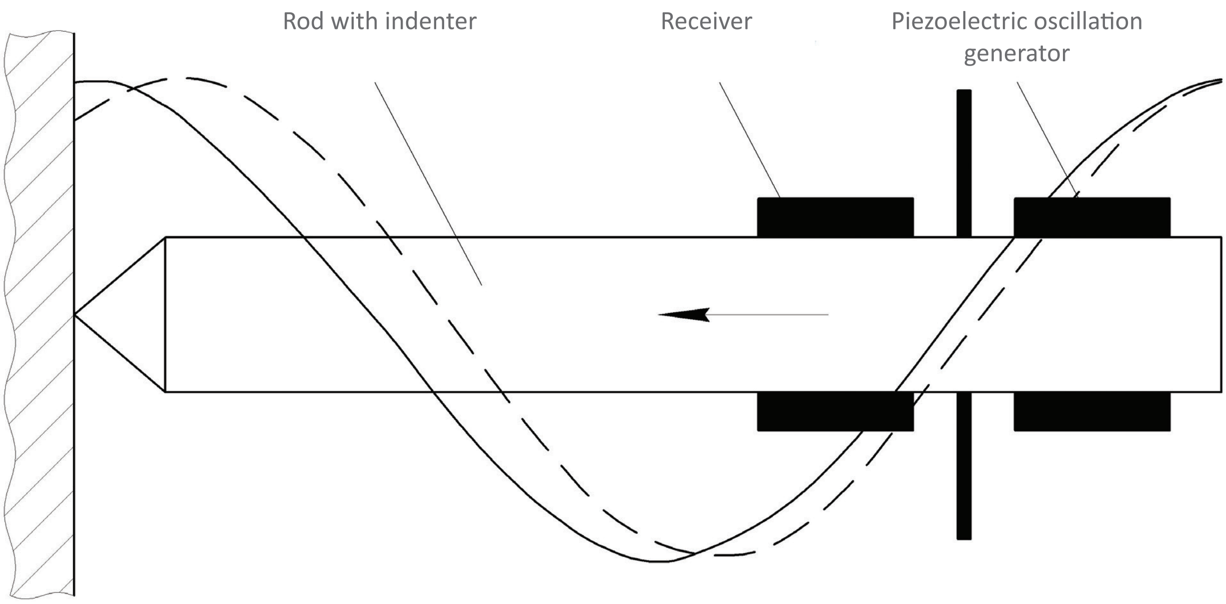
UCI measurement probes



Method description

The ultrasonic contact impedance method is based on the effect of change of own frequency of the oscillatory system. The system consists of an elastic element (rod) included in an autogenerating circuit. An indenter is fixed to the end of the rod. When the indenter is forced into the surface of the test sample the frequency of the oscillatory system changes due to the increase of system stiffness.

Operation principle of the measurement probe

The sensitive element of the probe is a steel rod with the indenter (Vickers pyramid-shaped diamond) with piezoelements fixed on it, which are connected to the generator and the receiver of the oscillations. In the absence of contact with the surface, the rod oscillates at a frequency of ~80 kHz. When the indenter is forced into the test sample as a result of the load application, the frequency of the rod oscillations changes depending on the indentation depth h. The change in frequency is proportional to the area of contact of the indenter with the surface. When the maximum load is reached (1, 5 or 10 kg, depending on the modification of the measurement probe), the frequency shift ΔFr is measured. The hardness number HV (UCI) is determined from the calibration characteristics HV (ΔFr), which relates the hardness value to the change of the oscillation frequency of the rod.

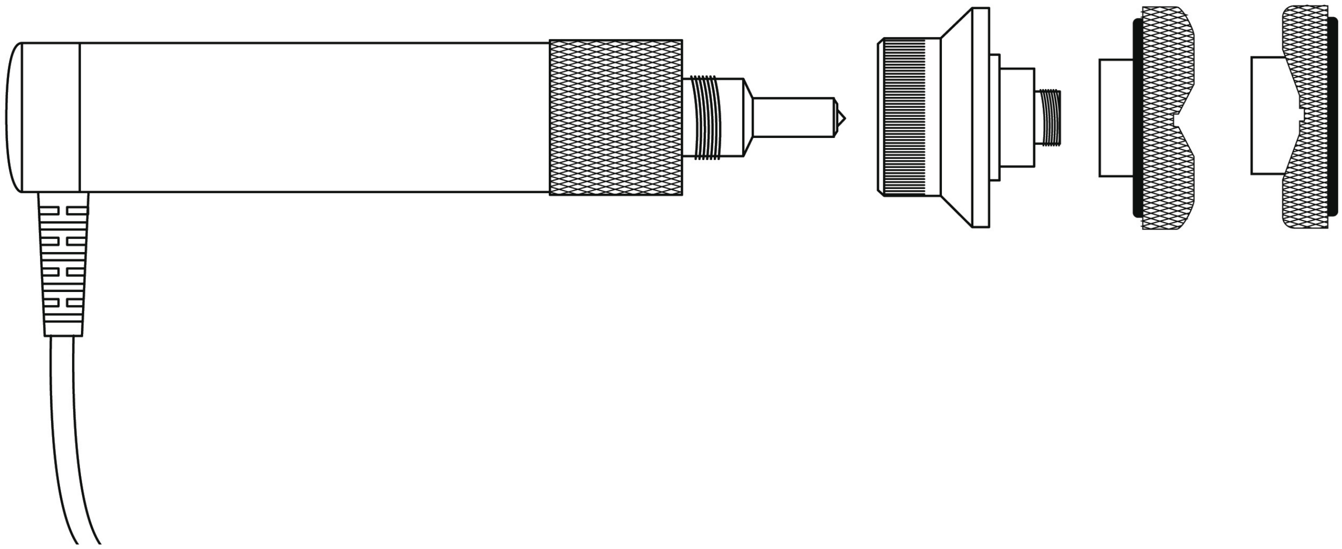
Application field

UCI method hardness testers are widely used as a portable replacement to the stationary Vickers hardness testers due to high level of correlation of the measured data. In addition, unlike the stationary Vickers hardness testers, here is no need of the optical assessment of the restored indentation, which speeds up the measurement process. In the case of measurement with probe with 1 kg load the portable UCI hardness testers leave small and shallow indentation, which allows to test relatively thin coating and it also increases requirement to the preparation of surface and material structure (surface roughness should not exceed 30% of the indentation depth). During hardness tests it should be remembered that the depth of the indentation shall be ten times smaller than thickness of the tested coating. UCI hardness testers are also often used for inspection of the heat affected zone (HAZ) of welded joints.

Features

The stiffness of the indenter contact area with the surface, which leads to the frequency shift, is proportional to the indentation area and also depends on the elastic modulus value of the material. In any case, the factory calibration is done on hardness reference standards made of unalloyed or low-alloyed steel, therefore in the case of testing products from other materials, it is necessary to perform calibration on the samples of the tested material.

When testing materials with high hardness, the measurement results can vary widely due to the small depth of indentation and slight change of the oscillation frequency of the rod with the indenter. The minimum thickness of the test pieces must be more than 15 mm. In case of the failure to meet this requirement the sample can resonate at the own frequency (eg. thin sheets, pipes, etc.). This problem can be solved by placing the test sample on a heavy metal base, connecting them with a viscous paste, a lubricant or an oil film sufficient to avoid the elastic vibrations. But even with the use of such accessories, the thickness of the product less than 2-3 mm is not acceptable. Samples weighing less than 300 grams can self-oscillate when tested by the UCI method, which imposes a limitation of the minimum weight of the test sample.



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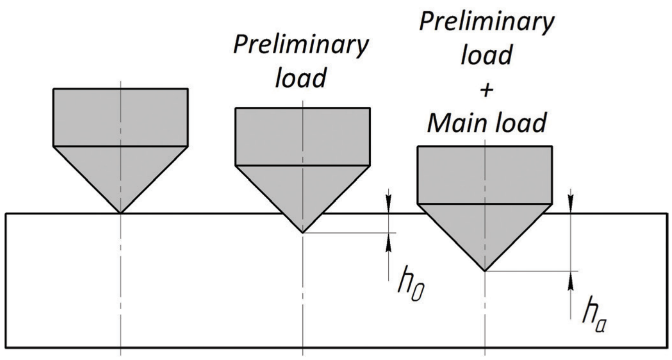
Standardisation

Currently, the measurements according to the UCI method are specified by DIN 50159 and ASTMA1038 standards. The measured hardness value with the application of the conversion tables stored in the device memory in accordance with standards ASTM E140 and ISO 18265 is converted in hardness value in the required scale HB, HRC, HV and others for the selected group of metals (alloys).

Application field and technical characteristics of different UCI measurement probes

	U–10N	**U–50N**	**U–100N**
Purpose	Inspection of parts with increased requirements for the indentation size, parts with surface hardened layer and galvanic coatings.	Universal standard probe for solving most of the industrial hardness measurement tasks.	For testing of parts with increased surface roughness, poorly prepared rough surface.
Test load, N (kg)	10 (1)	50 (5)	100 (1)
Minimum thickness of tested object*	2 mm		
Minimum mass of tested object, depending on configuration of tested object *	from 0.3 to 1 kg		
Diameters of indentations on products**, mm	0.058	0.130	0.180
Depth of indentations on products**, mm	0.017	0.038	0.052
Maximum surface roughness***, Ra, µm	0.8	1.6	3.2
Dimensions	Ø26 × 140 mm (Ø36 × 140 mm with flat foot)		
Features	Leaves significantly smaller depth and diameter of indentation compared to probe U-50N.	Best ratio between the dimensions of indentation and comfort work with the probe.	Lowest influence of surface roughness and other surface parameters of tested object

Portable Rockwell (PR) probes



Method description

The method is based on the measurement of the penetration depth of the indenter under the static load. Similarly to the Rockwell hardness measurement method, a preliminary and then full load are applied. The difference between the penetration depths at these loads is calculated into hardness values.

Probe operation principle

When making measurements with static PR probe, the values of the penetration depth of the indenter are continually recorded during the application of the preliminary and full loads. The applied load is 1 kg for preloading and 5 kg for the full load stage. At the time of application of the preload, the depth of penetration of the indenter into the material h0 is measured. After the application of the full load, the system takes a short time under load, after which the depth of penetration of the indenter into the material h_a is measured. Then the difference in the depth of penetration of the indenter is calculated according to the following formula:

$\Delta = h_a - h_0$,

where
h_a — indentation depth at full load,
h_0 — indentation depth at preliminary load.

The obtained difference between the penetration depths represents the level of plastic deformation of the tested material and is the direct measure of the materials hardness. Based on the received difference with the use of calibration characteristics the hardness of the material in HRC scale is defined.

A truncated cone with an angle at the vertex of 100° ± 0.5 ° and diameter of the top flat surface 0.06 mm ± 0.005 mm is used as an indenter for soft metals in PR probes. The indenter with flat top surface allows to reach stable readings of the indentation during preliminary load. PR probe with a sharp cone-shaped indenter with an angle of 100 °- 0.5 ° is used for hard metals. The sharp indenter allows to increase the probe's hardness operating range.

Application field

The PR method covers a fairly wide range of applications. Due to the fact that the method can be considered fully static, it has no limitations related to the Leeb and UCI methods. PR probes are ideal for hardness testing on small, light, thin, thin-walled or tubular objects, and for the hardness testing of massive machine parts.

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Features

Compared with the previously described methods, the PR method takes a bit longer to take the measurements and it is also impossible to measure in hard-to-reach places. The thickness of the test samples should be 10 times bigger than the depth of penetration.

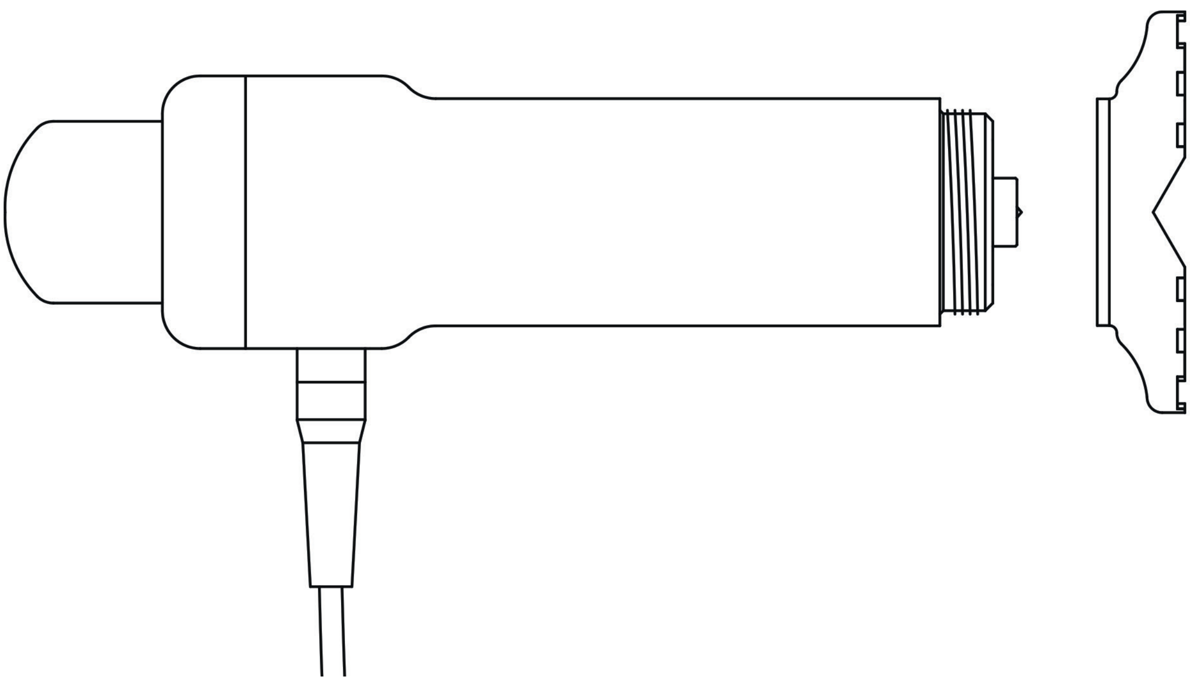
Standardisation

Currently, the measurements according to the Portable Rockwell method are specified by standards DIN 50157-1:2008 and ASTM B724-00(2006).

The measured hardness value with the application of the conversion tables stored in the device memory in accordance with standards ASTM E140 and ISO 18265 is converted in hardness value in the required scale HB, HRC, HV and others for the selected group of metals (alloys).

Main technical characteristics of the measurement probe

Accuracy of the indentation depth measurement, maximum, µm	±0.3(ASTM E18–03)
Test load:	
preload, N, (kg)	10 (1)
preload and main load, N, (kg)	50 (5)
Diamond indenter - truncated cone:	
wedge angle, deg.	100 ± 0.5
top surface diameter, µm	60 ± 5
Overall dimensions, mm	Ø53 × 105
Weight, g	340

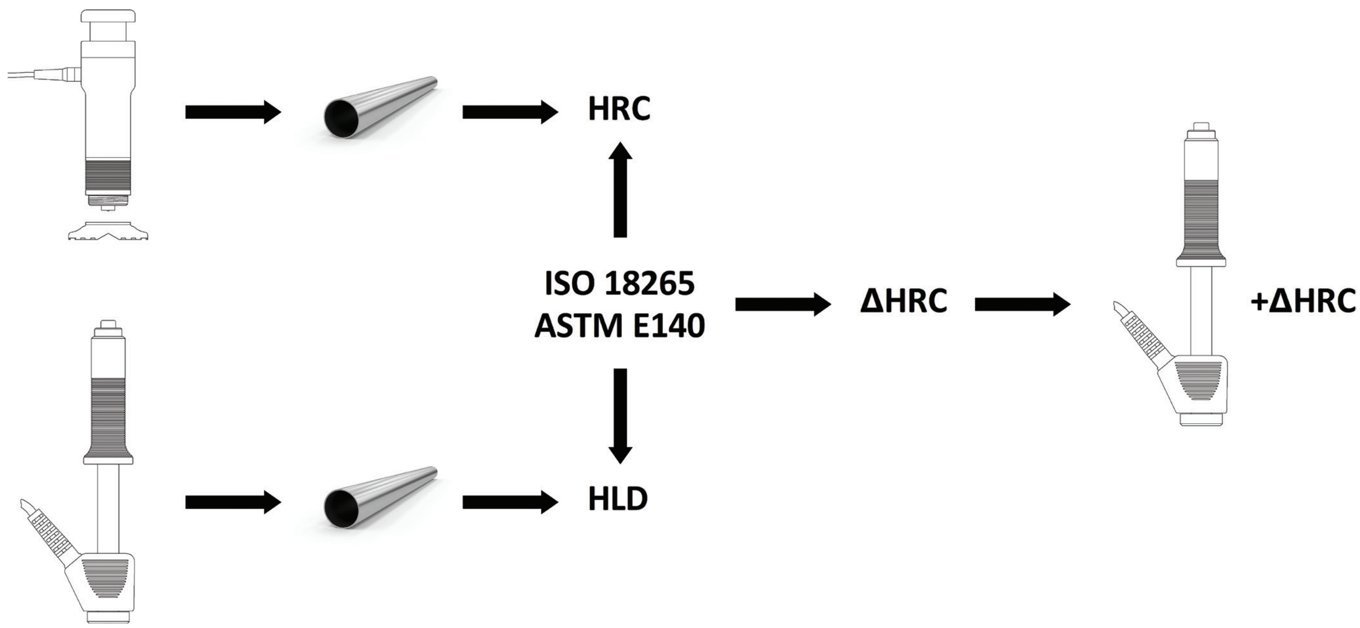


Methodical principles of complex approach for hardness testing

The complex approach to the hardness testing with use of several types of the measurement probes allows to inspect materials and objects, which do not meet the defined limitations for individual methods.

In particularly, the measurements with PR probe are practically not limited by thickness and mass of the test sample piece. For example, after the hardness measurement of a thin-walled pipe with this probe it is possible to define the correction coefficient for the measurement results by Leeb method, for which the wall thickness is a serious limitation. Similarly, the user can specify himself the correlation dependencies between different hardness scales for materials, for which there is no standard conversion table. As an example an algorithm for measurement results correction with use of PR probe and D probe according to Leeb method is given below.

To implement the complex approach it is necessary to:
1. Make at least five hardness measurements on the tested surface with PR probe with use of the required scale. Store the average value of the measurement results.
2. Make at least five hardness measurements with Leeb method probe with the required scale in the same area. Store the average value of the measurement results.
3. Take the measurement results obtained by PR probe as a reference values and input the correction of the probe readings according to the Leeb method relatively to the static probe readings in hardness values for the required scale. In the course of further testing by the Leeb method probe the received offset value will be automatically taken into account by the programme when displaying the measurement results.



This complex approach is described in detail in the operating manual for the hardness tester.

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Mutual correspondence of different hardness scales and the possibilities of their measurement by portable hardness testers

When portable hardness testers are used, inevitably arises the question of comparing the measurement results with the most common and generally accepted Brinell, Vickers and Rockwell hardness scales. Despite the fact that hardness measurement is one of the most common methods to test mechanical characteristics, unambiguos determination of hardness as a material property does not exist. Hardness numbers do not belong to the main (primary) characteristics of the material, but they depend on the method of their measurement, defined as a hardness scale.

To ensure the measurements uniformity in a specific hardness scale it is necessary not only to standardise the method, but also create a metrological infrastructure to ensure traceability of the measurement results. This metrological infrastructure includes the hardness reference test blocks, standard machines to calibrate the reference test blocs and also the primary reference standards approved at the national level and passing the international comparison. Such a system of the standardisation and metrological provision created for Brinell, Rockweel, Vickers and other scales allows to compare measurement results, taken all over the world, between each other within each scale. In practice, the question of comparison of the materials mechanical properties, measured by different hardness scales, arises periodically. Experimental data and scientific research indicate that there are no universal dependencies connecting the hardness numbers of different scales. In terms of metrology, the hardness numbers, composing the order scales, can only be compared within the same scale. A comparison of numbers from different order scales is unacceptable. At the same time, in particular cases, it is possible to establish a relationship between hardness scales expressed in the form of a conversion table or an equation obtained by regression analysis of experimental data.

The large amount of experimental data accumulated over many years has made it possible to compile conversion tables between different hardness scales. In addition, a large number of studies has been carried out that have made it possible to establish a relationship between the hardness numbers of different scales with one of the main characteristics of materials - the tensile strength σ. These data are generalised in international standards ASTM E140 and ISO 18265. However, all available tables and conversion equations between different hardness scales are empirical in nature and are defined for specific classes of materials in a limited range of mechanical properties and measurement conditions.

Most hardness measurement methods implemented by portable hardness tester do not meet the standards for conventional hardness scales. Standards for these methods determine only the equipment parameters and measurement procedures, but do not contain requirements for metrological traceability. The exception are the scales based on the Leeb method, for which the metrological requirements for the measurement instruments, the hardness reference test blocks and the standard hardness machines are defined and the national primary standards exist.

The measurement results of portable hardness testers expressed in conventional scales do not fully represent the values of these scales, but represent the results of conversion of the values measured by the devices in hardness numbers of the selected scale from the table or formula stored in the device memory. The selection of the table depends critically on the material of the test piece. The reliability and accuracy of such conversion depends on how much the materials, for which the table is made, correspond to those, properties of which are tested.

The following conclusions can be drawn from the foregoing:

— The most accurate and reliable hardness values in the required scale can only be obtained by applying standardized procedure for this scale.

— Any conversion and recount procedures introduce an additional, sometimes unpredictable (unknown), uncertainty in the obtained result. This also applies to the scales based only on the physical principle, for example, plastic deformation under static load in case of Brinell, Rockwell and Vickers scales.

— Significantly less reliable and accurate is the relationship between these static scales and dynamic hardness in Shore and Leeb scales, which represent not only the plastic characteristics, but also the elastic properties of the material.

— Hardness values received by ''indirect'' methods by conversion while applying the conversion tables can only be used as a reference. Such tables can be used when all the conditions for conversion, taking into account the requirements and limitations of ISO 18265 and ASTM E-140, are fulfilled.

Despite the above given requirements and limitations, the portable hardness testers are very effective tool for an operative inspection of products parameters. When solving a specific measurement task, the user usually deals with pre-known materials with a certain range of mechanical properties. This allows to correctly select the conversion table and obtain reliable data. In addition, modern portable hardness testers usually have the function of creation of custom conversion table or correction of the existing dependencies.

Multifunctional portable hardness tester KT-C provides users with the possibility to test hardness of materials in accordance with the international standards and displays the measurement results in conventional hardness scales according to the approved conversion tables. The software in the device allows to create user's conversion tables and formulas. The presence of three different probes operating on different physical principles provides a unique opportunity to correct the conversion tables in dependency on the actual properties of the measured materials and to obtain the most reliable and accurate measurement results.

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