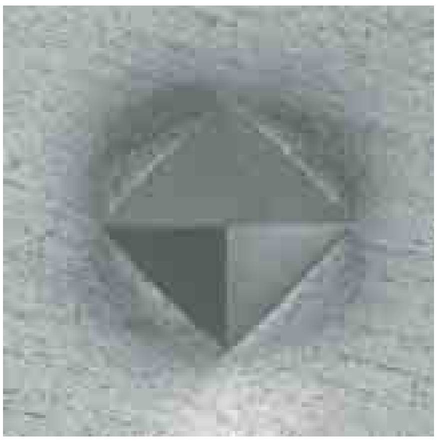
Zwick / Roell

Zwick
Materials Testing

Hardness testing with Zwick



FP 303 2.0802.302

Contents

Zwick / Roell

1. Zwick materials testing

Zwick is known worldwide especially for the manufacture of **materials testing machines** and accessories, as well as in the development of electronics and test software. Zwick has gathered over 50 years of comprehensive knowledge in these areas, you can use this knowledge to your advantage.

The Zwick quality management was certified to DIN EN ISO 9001 way back in 1993.

Zwick materials testing machines
- ensure the constant quality of your materials and products,
- reduce your company's risk of liability by monitoring and controlling production parameters,
- build up trust in your business partners through traceable test results within the framework of ISO 9000 etc.

Zwick offers, since many years, not only stationary hardness testers but also a wide range of portable hardness testers.

The hardness product range has been considerably expanded owing to new developments. Thus we now have a comprehensive range of hardness testing machines for each application.

Fig. 1: The most universal hardness testing machine in the world: the ZHU2,5/Z2,5

Zwick hardness testing machines and hardness testers:

Economy:
- low cost solutions for standard applications,
- can be put to universal use, e.g. goods received, production control, research and development,
- optimum price-performance ratio for all requirements.

Flexibility through modular construction:
- tailor made solutions for test tasks through the modular construction system of the hardness testing machines/hardness testers and accessories, inclusive of the software,
- machines for the future through the possibility of subsequent retrofitting,
- short delivery times.

Add-ons via a wide range of accessories:
- different hardness test devices for Zwick materials testing machines to standardised and customised specifications,
- indentors for all usual test methods,
- a range of prismatic specimen supports/holders,
- different specimen vices,
- manual and motorised compound tables,
- certified hardness comparison plates.

We support you
before and after purchase
- through technical consultants in outside sales,
- through tests in our applications laboratory,
- through hotline support and service.

Zwick hardness testing machines/hardness testers

The Zwick product palette encompasses a range of hardness testing machines and hardness testers for tests on metals, plastics, rubber and special materials.

Stationary hardness testing machines and hardness testers permit tests for
- Vickers hardness HV,
- Brinell hardness HB,
- Knoop hardness HK,
- Universal hardness HU,
- Rockwell hardness HR (scales A...K, N, T),
- Ball indentation hardness H,
- Hardness HVT,
- Hardness HBT,
- Hardness of carbon materials and carbon brushes,
- Hardness on construction gypsum,
- Hardness of asphalt,
- Hardness of resilient floor coverings.

Portable hardness testers cover the methods
- Shore hardness,
- IRHD hardness,
- Brinell hardness and
- Rockwell hardness.

Advantages of the Zwick hardness testing machines/hardness testers

Zwick offers a complete program of hardness testing machines and hardness testers from fully automatic hardness testing systems up to the basis device for standard applications.

The **hardness testing machines** result from the combination of Zwick materials testing machines with accessory devices for hardness tests and the test software *testXpert*®.
Flexibility and expansion possibilities permit tailor made, customer orientated solutions via
- hardness test devices for optical tests,
- the hardness measurement head for indentation depth measurement,
- combination of the hardness measurement head with a measurement microscope for hardness tests with optical indentation measurement and incremental depth measurement,
- compound table variants (manual or controlled via motor) and
- master and standard test programs from *testXpert*®.

Fig. 2: Different specimen for hardness tests

The hardness testing machines are
- constructed in a modular system, and are flexibly combinable,
- designed for almost unlimited expansion and retrofits,
- capable of being automated, and can be intergrated in automatic test systems,
- equipped with digital measurement and control technology as standard,
- a guarantee for investment and future security.

The spectrum of **hardness testers** contains devices with
- one-button operation for simple applications,
- line display and integrated conversion functions to other hardness scales for standard applications,
- touchscreen, expanded functions and high operator comfort for comprehensive test tasks such as batch tests and production control.

The hardness testers are distinguished by
- simple operation,
- automatic test cycle,
- manual or automatic load changing,
- flexible/large test area height,
- high precision,
- robust construction with play free ball lead screw,
- a wide range of accessories.

Zwick / Roell

2. Basics, standards and selection of the hardness test methods for metals, plastics and rubber

Round about 1900 Martens suggested the following as a **terminology definition**: “Hardness is the resistance that a body offers to indentation by another (hard) body”. This simple but precise definition has taken its place in technical circles, and is just as valid today as then. The technical hardness is a mechanical quantity for describing a material or the state of a material.

The hardness cannot be measured directly, it must be derived from **primary measurement quantities** (e.g. test load, indentation depth, indentation area. Depending upon the hardness test method, the hardness value is determined from

- the test load and a geometrical quantity determined by the indentation, e.g. indentation depth,
- solely via the length characterising the hardness indentation,
- through another material answer, e.g. scratch resistance.

Hardness values can only be compared if they have been determined via the same test method with identical test parameters.

An **explicit hardness value** can only be characterised via the following criteria:

- definition of the hardness value (see page 6 onwards),
- indentor’s geometry and material,
- size and indentation duration at test load, as well as the type of loading,
- state and surface quality of the specimen.

The following is at the forefront for **selection of a hardness test method**:

- economy,
- time for specimen preparation,
- availability of machines and devices.

Furthermore, selection of the suitable hardness test method depends upon the

- specimen material and hardness,
- shape, dimensions and accessibility of the specimen,
- task at hand (e.g. series or hardness sequence tests) and
- permissible measurement uncertainty.

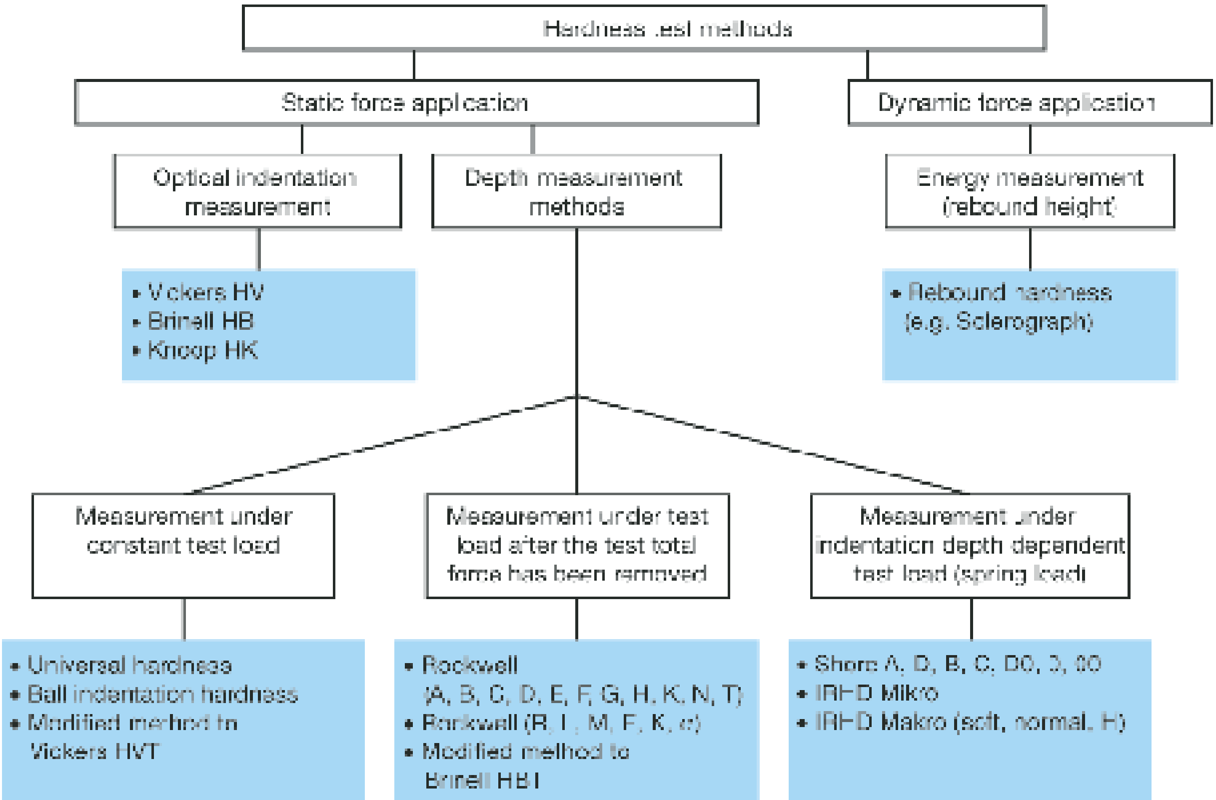


Fig. 3: Overview of hardness test methods

2.1 Hardness tests on metals

Mainly methods with **static force application** are used for metals. The indentor (ball, cone, pyramid) made of steel, hard metal or diamond is pressed into the surface of the specimen which is placed on a hard and fixed base. The test load is applied bumplessly with a defined application time and duration. The indentation is measured after load removal for many test methods.

The length measurement value (indentation depth, diagonals, diameter) and the test load are used for calculating the hardness value. Generally the hardness test methods Rockwell, Brinell and Vickers (Knoop) are used. The universal hardness test is currently not widely used in industry. Its position will, however, increase considerably in importance over the next few years.

Methods with dynamic force application are applied to large components via mobile devices especially for hardness tests.

Fig. 4: The Zwick hardness measurement head is used for hardness tests on metals

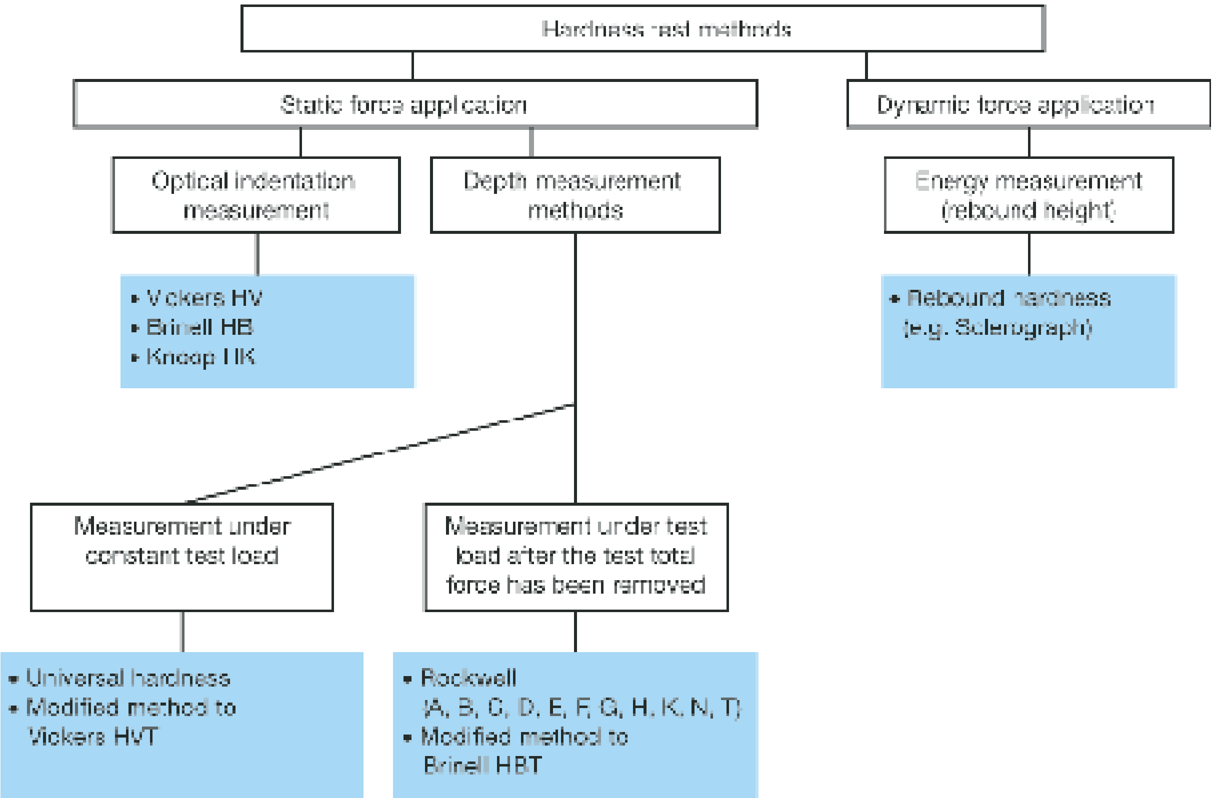
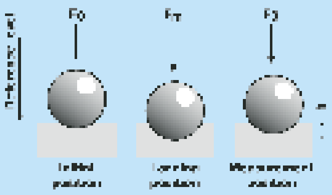


Fig. 5: Hardness test method for tests on metals

Zwick Roell

2.1.1 Short description of the hardness test method

Hardness testing to Rockwell (A, B, C, D, E, F, G, H, K, N, T)



Measurement quantity
Rockwell hardness HR.
The indentation depth h is measured in mm.

Definition
HR = N - h/S
N ... Numerical value (determined for each Rockwell method)
h ... Remaining indentation depth in mm
S ... Scale value in mm
This value is the change in indentation depth in mm that corresponds to one Rockwell unit.

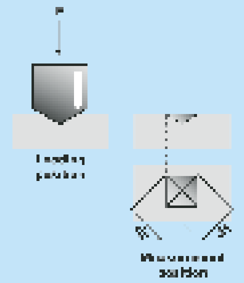
The different Rockwell methods and more precise details are listed in table 1 below (page 11).

Display of the test result:
e.g. 61,2 HRC
- Code letter for the selected Rockwell method
- Code letter for Rockwell hardness
- Hardness value

Advantages
+ little time required for carrying out the test as the hardness value can be read off directly following indentation, or it is displayed
+ possibility of automation
+ low procurement costs for the test machine as no optical measurement device is necessary
+ no operator influence as the hardness value is displayed direct

Disadvantages
- possibility of error during the test sequence caused by permanent shifting of the specimen, and of other components that are in the force flow during the test
- limited possibility of the test of edge zone hardened specimen owing to high test loads
- sensitivity of the diamond indentor against damage, thus danger of erroneous measurements
- poor differentiation of the hardnesses
- influence of the indentor on the hardness test result when using a conical indentor

Hardness tests to Vickers



Measurement quantity
Vickers hardness HV. The lengths of both diagonals of the remaining test indentation are measured.

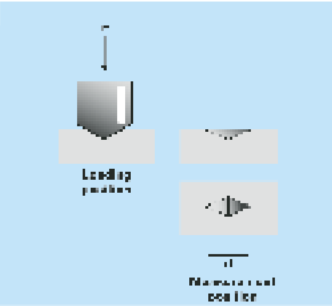
Definition
HV = 0,102 F/A
= 0,1891 F/d²
F ... Test load in N
A ... Indentation surface in mm²
d ... Arithmetic average value of the diagonal lengths in mm

Display of the test result
e.g. 230 HV 10/20
- Indentation duration in s (not applicable for standardised duration)
- Prefix for the test load, corresponds to F in N · 0,102
- Code letter for Vickers hardness
- Hardness value

Advantages
+ almost no limit to the use of the method via the specimen's hardness
+ tests on thin sheet metal, small specimen or test areas, thin walled tubes, thin hardness and galvanic layers is possible
+ as the indentations can be kept very small, the functionability is retained in most cases
+ independency of the hardness value from the test load in the macro range (test loads > 49,03 N)
+ no erroneous measurement at specimen yield in the direction of action of the test load

Disadvantages
- time consuming to achieve sufficient surface quality
- time required for measuring the diagonal lengths
- sensitivity of the diamond indentor to damage
- small indentations make the hardness dependent upon the shape deviations of the indentor, and of the test surface preparation
- susceptible to vibrations especially in the micro range
- operator influence on the hardness value

Hardness tests to Knoop



Measurement quantity
Knoop hardness HK. The length of the long diagonal of the remaining test indentation is measured.

Definition
HK = 0,102 F/A
= 1,451 F/d²
F ... Test load in N
A ... Projection area of the indentation in mm²
d ... Length of the long indentation diagonal in mm

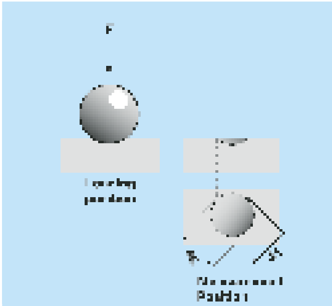
Display of the test result:
e.g. 1240 HK 0,5/30

- 30: Indentation duration in s (not applicable for 10 to 15 s)
- 0,5: Prefix for the test load, corresponds to F in N · 0,102
- HK: Code letter for Knoop hardness
- 1240: Hardness value

Advantages
+ suitable for small specimen owing to the high diagonal length ratio of approx. 7:1
+ better than Vickers for thin specimen or layers as the indentation is not so deep (by the factor 4) but the diagonal lengths are the same
+ suitable for brittle materials owing to the low susceptibility to cracking
+ suitable for research into the anisotropy of a material as the Knoop hardness is dependent upon the selected direction for the long diagonal in such a case
+ no influence on the functionality of the test surface owing to the shallow test indentations

Disadvantages
- time consuming to achieve a sufficiently fine test area
- dependency of the hardness on the test load
- sensitivity of the diamond indentor to damage
- time consuming alignment of the test surface to achieve symmetrical test indentations

Hardness tests to Brinell



Measurement quantity
Brinell hardness HB. Two diameters, at right angles to one another, of the remaining indentation in the specimen surface are measured.

Definition
HB = 0,102 F/A
$= 0{,}102 \cdot 2F / (\pi D(D - \sqrt{D^2 - d^2}))$
F ... Test load in N
A ... Indentation surface in mm²
D ... ball indentor dia. in mm
d ... arithmetic average from two measured indentation diameters in mm

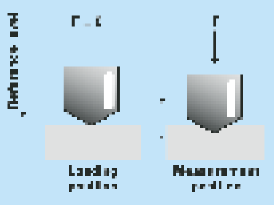
Display of the test result:
e.g. 205 HBW 10/3000/30

- 30: Indentation duration in s (not applicable for standardised duration 10 to 15 s)
- 3000: Prefix for the test load, corresponds to F in N · 0,102
- 10: Diameter of the ball indentor in mm
- W: Code letter for indentor ball material (hard metal)
- HB: Code letter for Brinell hardness
- 205: Hardness value

Advantages
+ suitable for hardness tests on inhomogeneous materials owing to the large indentation, as long as the expansion of the inhomogeneity is small in relation to the indentation
+ suitable for hardness tests on large unfinished parts such as forged parts, cast parts, hot rolled or pressed and heat treated parts
+ no erroneous measurement at specimen yield in the direction of action of the test load
+ simple and robust indentor

Disadvantages
- limitation of the range of application for a maximum Brinell hardness of 650 HBW
- limitation for testing small and thin specimen
- time consuming for measuring the indentation diameter
- relatively large degree of damage to the specimen by the indentation

Universal hardness testing



Measurement quantity
Universal hardness HU. The indentation depth h under test load is measured.

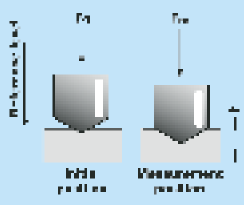
Definition
HU = F/A = F/ (26,43 h²)
HU ... Hardness value in N/mm²
F ... Test load in N
A ... Indentation surface under test load in mm²
h ... Indentation depth under test load in mm

Display of the test result:
e.g. HU 100/20 = 3200 N/mm²
- Units
- Hardness value
- Duration of test load application in case of deviation from the set duration
- Test load in N
- Code letter for universal hardness

Advantages
+ use for all materials
+ possibility of automation
+ use in production control
+ determination of the hardness value from elastic and plastic deformation
+ independency of the hardness value from the test load for indentation depths ≥ 10 µm
+ additional information on the material via the force-indentation depth curve
+ Additional characteristics are possible via the mechanical material behaviour (relaxation/creep of the material, elastic and plastic portion of the indentation work, plastic hardness, elastic indentation modulus)

Disadvantages
- smaller indentations increase the demands on the quality of the specimen surface (indentation depth ≥ 20 · average rough value)
- susceptible to vibrations especially in indentation depth range h < 15 µm
- possibility of error caused by elastic and permanent shifting of the specimen, and of the component that's in the force flow during the test
- sensitivity of the method to shape deviations of the indentor, especially in the area of its tip

Modified method to Vickers HVT



Measurement quantity
Vickers hardness from depth measurement HVT. The indentation depth h under test load is measured.

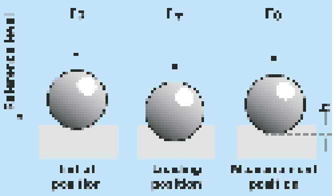
Definition
HVT = 0,102 F/A
= 0,102 F/(26,43 h²)
F ... Test load in N
A ... Indentation surface under test load in mm²
h ... Indentation depth under test load in mm

Display of the test result:
e.g. 320 HVT 10/20
- Indentation duration in s
- Prefix for the test load, corresponds to F in N · 0,102
- Code letter for Brinell hardness
- Hardness value

Advantages
+ use for all materials
+ possibility of automation
+ use in production control
+ determination of the hardness value from elastic and plastic deformation

Disadvantages
- smaller indentations increase the demands on the quality of the specimen surface (indentation depth ≥ 20 · average rough value)
- susceptible to vibrations especially in indentation depth range h < 15 µm
- sensitivity of the method to shape deviations of the indentor, especially in the area of its tip
- this method is not standardised

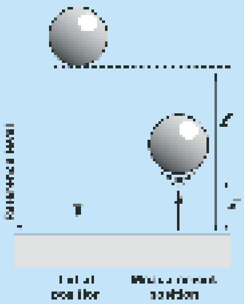
Modified method to Brinell HBT



Measurement quantity
Modified Brinell hardness HBT. The remaining indentation depth h in mm of the test indentation under test pre-load.

Definition
HBT = Hardness value that is gained by converting the indentation depth with the help of reference specimen.

Rebound hardness test



Measurement quantity
Rebound hardness. The impact velocity v_a and the rebound velocity v_r (or height) of the impact body.

Definition
Rebound hardness = $c \cdot v_r/v_a$
c ... Constant
v_r ... Rebound velocity of the impact body
v_a ... Impact velocity of the impact body

Display of the test result:
e.g. 205 HBT 10/3000
- Calibration method of the reference specimen
- Identifier of the test method
- Hardness value

Advantages
+ little time required for carrying out the test as the hardness value can be read off, or is displayed, directly following indentation
+ possibility of automation
+ little time necessary for preparation of the test surface
+ no operator influence as the hardness value is displayed direct

Disadvantages
- validity of the conversion relationship is very limited
- possibility of error during the test sequence caused by permanent shifting of the specimen, and of other components that are in the force flow during the test
- comparison measurements on different machines presuppose a common conversion relationship
- this method is not standardised

Display of the test result:
e.g. 540 HL
- Code letter for rebound hardness
- Hardness value

Advantages
+ extremely short test times
+ automatic test sequence
+ tests in all positions, e.g. also overhead measurement by using correction factors
+ simple handling
+ portable device
+ direct display of the hardness value

Disadvantages
- test of specimen that are thin or of low mass is problematic
- this method is not standardised

Zwick / Roell

2.1.2 Tabular summary: Hardness tests on metals

Method	Abbreviation	Indentor	Test pre-load	Test total force	Measurement quantity/range	Test standard
Rockwell					Rockwell hardness HR	
Scale A	HRA	Diamond cone	98,07 N	588,4 N	20 ... 88 HRA	DIN EN ISO 6508-1
Scale B	HRB	Ball, Ø 1,5875 mm (1/16 inch)	98,07 N	980,7 N	20 ... 100 HRB	DIN EN ISO 6508-1
Scale C	HRC	Diamond cone	98,07 N	1471 N	20 ... 70 HRC	DIN EN ISO 6508-1
Scale D	HRD	Diamond cone	98,07 N	980,7 N	40 ... 77 HRD	DIN EN ISO 6508-1
Scale E	HRE	Ball, Ø 3,1750 mm (1/8 inch)	98,07 N	980,7 N	70 ... 100 HRE	DIN EN ISO 6508-1
Scale F	HRF	Ball, Ø 1,5875 mm (1/16 inch)	98,07 N	588,4 N	60 ... 100 HRF	DIN EN ISO 6508-1
Scale G	HRG	Ball, Ø 1,5875 mm (1/16 inch)	98,07 N	1471 N	30 ... 94 HRG	DIN EN ISO 6508-1
Scale H	HRH	Ball, Ø 3,1750 mm (1/8 inch)	98,07 N	588,4 N	80 ... 100 HRH	DIN EN ISO 6508-1
Scale K	HRK	Ball, Ø 3,1750 mm (1/8 inch)	98,07 N	1471 N	40 ... 100 HRK	DIN EN ISO 6508-1
15 N	HR 15N	Diamond cone	29,42 N	147,1 N	70 ... 94 HR 15 N	DIN EN ISO
30 N	HR 30N	Diamond cone	29,42 N	294,2 N	42 ... 86 HR 30 N	6508-1
45 N	HR 45N	Diamond cone	29,72 N	441,3 N	20 ... 77 HR 45 N	
15 T	HR 15T	Ball, Ø 1,5875 mm	29,42 N	147,1 N	67 ... 93 HR 15 T	DIN EN ISO
30 T	HR 30T	(1/16 inch)	29,42 N	294,2 N	29 ... 82 HR 30 T	6508-1
45 T	HR 45T		29,42 N	441,3 N	1 ... 72 HR 45 T	
Vickers						
Micro	HV 0,01...≤ 0,2	Diamond pyramid,	-	0,098...1,961	Vickers hardness HV	DIN ISO 4516,
Low load	HV 0,2...≤ 5	angle of the faces	-	1,961...49,03	Vickers hardness HV	DIN EN ISO
Macro	HV 5...100	136°	-	49,03...980,7N	Vickers hardness HV	6507-1
Knoop						
	HK	Rhombic diamond pyramid	-	≤ 9,807 N	Knoop hardness HK	ISO 4545 DIN ISO 4516
Brinell						
	HBW	Ball, Ø 1/2,5/5/10 mm	-	9,807... 29420 N	Brinell hardness HB	DIN EN ISO 6506-1

Degree of loading	**30**	**10**	**5**	**2,5**	**1**
Indentor ball Ø in mm			Test load F in N		
10	29420	9807	4903	2442	980,7
5	7355	2452	1226	612,9	245,2
2,5	1839	612,9	306,5	153,2	61,29
1	294,2	98,07	49,03	24,52	9,807
Recordable hardness range	96-650	32-218	16...109	8...55	3...22
Examples	Steel, cast, maleable cast iron	Alu, brass, copper, bronze	Aluminium, zinc	Aluminium	Lead, tin

Table 1: Overview of standards and methods for metals

Continuation of tabular summary: Hardness tests on metals

Method	Abbreviation	Indentor	Test pre-load	Test total force	Measurement quantity/range	Test standard
Universal hardness						
	HU	Diamond pyramid, angle of the faces 136°	-	2...2500 N	HU	DIN 50359-1, DIN EN ISO 14577-1
	HU	Berkovich diamond pyramid, hard metal balls	-	2...2500 N	HU	
Method HVT						
	HVT	Diamond pyramid 136°	~1,96	1,961 ... 980,7 N	Vickers hardness HVT	this method is not standardised
Method HBT						
	HBT	Ball, Ø 2,5/5/10mm	1961 N; 980,7 N; 490,3 N; 98,07 N	29420 N ... 612,9 N	Brinell hardness HBT, ≤ 650 HBT	this method is not standardised
Rebound hardness test						
	HL	Spherical, radius 1,5 ... 2,5 mm	-	E = 3,0 mJ ... 90,0 mJ	Rebound hardness	this method is not standardised

Table 1: Overview of standards and methods for metals

Test method Rockwell	Applicational ranges
HRA	Hardened steels of lower thickness or with thinner layers as those required for HRC can be tested. Lower material loading and specimen damage as is the case with HRC. Hard metals.
HRD	Surface hardened parts with hardness layers.
HRC	Hardened steels (tools, high strength construction steel).
HRF	Cold rolled, steel sheet metal, annealed copper-zinc alloys and annealed copper.
HRB	Soft construction steel (sheet metal), non-ferrous metals.
HRG	Phosphor bronze, beryllium copper, malleable cast iron of low hardness.
HRH	Aluminium, zinc, lead.
HRE	Cast iron, aluminium and magnesium alloys, bearing metals.
HRK	Bearing metals and other metals of low hardness.
HR 15/30/45 N	Steels such as HRA, HRD and HRC, as long as thin parts or zone layers are available.
HR 15/30/45 T	Soft steels and non-ferrous metals such as for HRF and HRB, as long as thin parts are available, e.g. deep drawn sheet metal.

Table 2: Overview of applicational ranges for Rockwell tests

2.1.3 Converting hardness values

Amongst others it's necessary to convert hardness values determined by one method to those of another method. This is usually the case if a hardness testing machine is not available for a required method, or if the specimen, for space reasons, cannot apply an indentation to the specimen.
Owing to local, different hardness with many materials, such **conversions** only present coarse indications of the actual hardness value and should only be used if the correctness of the conversions is sufficiently guaranteed.
Empirical conversions exist with limited accuracy for certain materials between the hardness methods Brinell, Vickers and Rockwell as well as between the hardness and tensile strength. Generally valid conversion relations don't exist.

Details are contained in DIN 50150.
The following is valid as rule of the thumb for estimations[1]:

HB ↔ HV: HB ≅ 0,95 x HV
HRB ↔ HB: HRB ≅ 176 - 1165/√HB
HRC ↔ HV: HRC ≅ 116-1500/√HV
HV ↔ HK: HV ≅ HK (in the low-load range)
R_m ↔ HB, HV: $R_m \cong c$ HB (or HV), R_m in N mm^{-2}

The factor c for estimating the tensile strength R_m is usually suggested as:
c ≅ 3,5 for steel (krz-Fe-Matrix)
c ≅ 5,5 annealed for Cu and Cu alloys
c ≅ 4,0 cold forged for Cu and Cu alloys
c ≅ 3,7 for Al and Al alloys

[1]... from: "Werkstoffprüfung", Horst Blumenauer, 6. Auflage, 1994

2.2 Hardness tests on plastics and rubber

The hardness of plastics can, in principle, be determined with the **methods** of the metals hardness testing. However, the hardness test methods ball indentation hardness, Shore A/D hardness as well as IRHD hardness and Rockwell hardness (scale R...K, α) have proven to be the preferred methods.

The reasons for this are, on the one hand, the quite often strongly pronounced, time dependent material behaviour of polymer materials, and, on the other hand, the low contrast ratio of the plastic indentation to the surface.

The applied test methods therefore usually include a measurement of the indentation depth under test load and a defined hold time. The method of the **universal hardness** test with continuous measurement of the test load indentation depth sequence at load application/removal offers advantages which permits expectancy of increasing use of this test method. Further advantages are in the evaluation possibilties of the test load-indentation depth sequence for determination of mechanical materials characteristics. The material relaxation and creep can be determined in a simple manner.

Fig. 6: The Zwick hardness measurement head with automatic specimen feed will be put to use for fully automatic hardness tests on plastics

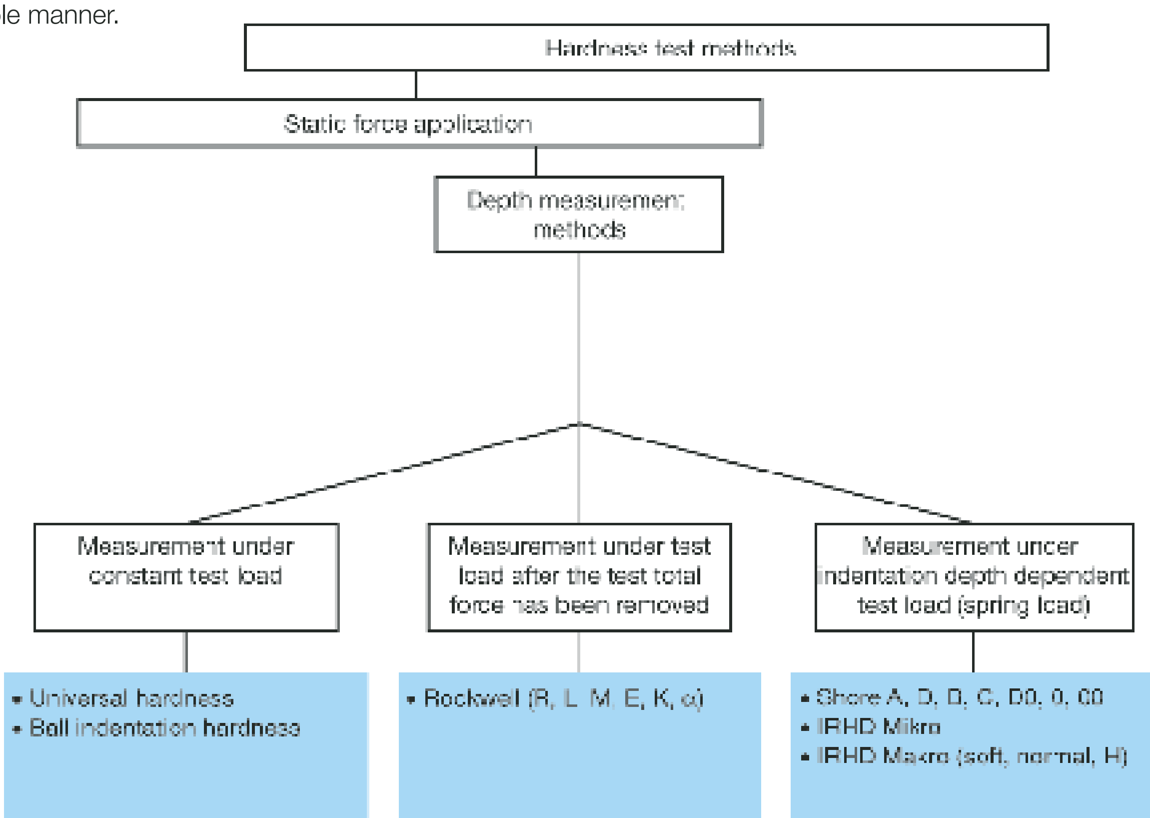
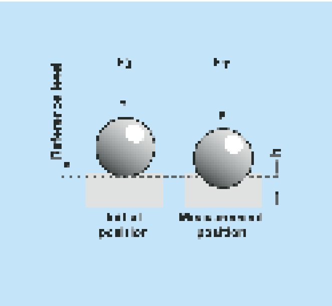


Fig. 7: Hardness test methods for tests on plastics

2.2.1 Short description of the hardness test method

Ball indentation hardness



Measurement quantity
Ball indentation hardness H. The read off indentation depth, corrected by the test device flexure, is measured.

Definition
The ball indentation hardness H is the quotient from the test load and surface of the test indentation of a ball acting under a test load.

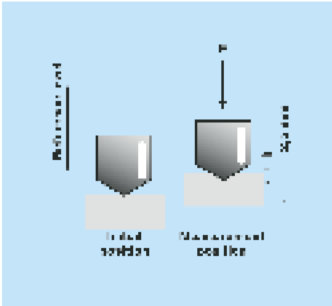
Display of the test result:
e.g. H 132/60 = 20 N/mm²

- Hardness value in N/mm²
- Duration of loading in s if it deviates from that prescribed in the test standard
- Test total force in N
- Abbreviation of the method

Advantages
+ suitable for hardness tests even under rough conditions
+ owing to the relatively large indentations, suitable for testing the hardness of inhomogeneous and/or anisotropi-cal materials so long as the expansion, e.g. filler caused inhomogeneities are small in relation to the test indentation
+ suitable for hardness tests on large finished parts or on semi-finished parts as long as deformations caused by the test can be excluded by appropriate support of the parts to be tested on the hardness tester's support table
+ simple and robust indentor
+ capability of being rationalised or automated by the test sequence and evaluation in the sense of online data processing

Disadvantages
- limitation when testing small specimen owing to necessary distance(s) (≥ 10 mm) between the test indentations, as well as the specimen edge
- limiting the applicational range, especially at low hardness; the least possible hardness to be determined according to test standard is H 49/30 = 8,5 N/mm² (corresponds to, for example, the hardness of soft PVC with approx. 25 - 27% DOP as plasticizer)
- multiple chaning of test load stages is necessary, as long as changes in states of plastics is to be followed up via hardness test measurements (e.g. caused by heat or plasticizing medias)
- no standardised procedure available for indirect, i.e. including all of the device's components, monitoring of the hardness tester via hardness comparison plates
- no calibrated hardness comparison plates are available

Shore hardness



Measurement quantity
Shore hardness. The indentation depth is measured in mm.

Definition
The Shore A or D hardness is the difference between the numerical value 100 and the indentation depth of the indentor, in mm, divided by the scale value 0,025 mm under loading of the test load.

Shore A and D tests are the tests carried out most frequently. The Shore B, C, D0, 0, 00 methods are not used very much.

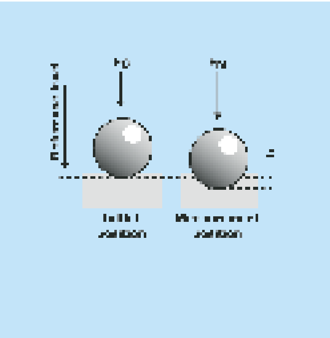
Display of the test result:
e.g. 75 Shore A 15

- Duration of test load application in s if it deviates from that prescribed in the test standard.
- Abbreviation of the method
- Code letter for Shore hardness
- Hardness value

Advantages
+ method of hardness tests on elastomers used worldwide
+ small testers, simple arrangement resulting in low cost devices
+ simple operation
+ can be used in a laboratory with a test stand and defined load application pressure, and can also be used on site by pressing the tester vertically onto the specimen by hand
+ tests on specimen or components are possible indepen-dent of gravity, even "overhead" or on vertical surfaces
+ moderate time required for specimen preparation; specimen dimensions ≥ 30 mm dia. or ≥ 30 mm · 30 mm level surface by cutting with a smooth bladed knife or by grinding with grain size 100
+ good repeatability and comparabilty of the method: repeatability 2 Shore (1 observer, 1 device), comparability 3 Shore (different observers, different devices) (values with test stand)
+ capability of being rationalised or automated by the test sequence (indentation depth measurement) and evaluation in the sense of online data processing

Disadvantages
- tests on small parts such as O-rings are not possible
- fractured surfaces lead to greater test data scatter
- specimen of thickness < 2 mm cannot be tested according to standard
- no calibrated hardness comparison plates are available
- testing without a test stand is relatively unexact

Ball indentation hardness of soft rubber, IRHD



Measurement quantity
International rubber hardness degree IRHD. The indentation depth is measured in mm.

Definition
The ball indentation hardness IRHD is a numerical value from a table that is determined by the respective indentation depth from loading the test load.

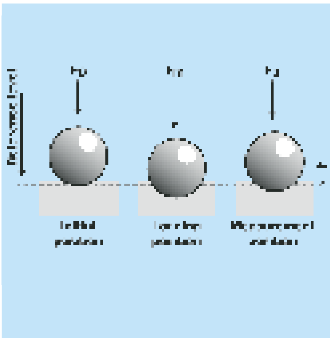
Differentiation is made between the methods IRHD macro method H, "normal" N and "soft" L as well as IRHD micro.

Display of the test result:
43 IRHD Micro
- Assignment to the micro hardness
- Abbreviation of the method
- Hardness value

Advantages
+ the test load generation via mass loading doesn't cause a temporal change of the force as can be observed with spring loaded indentors owing to creep or relaxation processes (e.g. as with the Shore A method)
+ indentation depth changes owing to relaxation or creep procedures at the time of test data recording are relatively small, this is caused by the long load application duration as compared to that for Shore A (application duration 3 s)
+ better reproducible test are achieved on concave or convex surfaces than with Shore A hardness tests
+ the hardness values to the IRHD macro method coincide with the IRH micro method at comparable material state of the elastomers: coincidence with Shore A hardness is only approximate for high elastic materials
+ as opposed to Shore A, the IRHD hardness values correlatebetter with physical characteristics (e.g. shear modulus)
+ the IRHD micro method can be used for small products or for products with dimensions of thickness or diameter down to 1 mm (e.g. O-rings)
+ local hardness differences can be recorded with the IRHD micro method

Disadvantages
- the IRHD macro method requires a relatively thick specimen
- test load generation via weights or low load application may cause vibrations, which in turn cause acceleration to the load application; use a suitable damping system
- owing to the low test loads and indentation depths the IRHD micro method is basically limited to use in laboratories
- no standardised procedure available for indirect, i.e. including all of the device's components, monitoring of the hardness tester via hardness comparison plates
- no calibrated hardness comparison plates available for plastics

Hardness tests to Rockwell (scales R, L, M, E, K, α)



Measurement quantity
Rockwell hardness HR. The indentation depth h is measured.

Definition
The Rockwell hardness is the difference between a numerical value and the indentation depth in mm divided by the scale value 0,002 mm through the supplementary test force and measured under the test pre-load.

Display of the test result:
e.g. 70 HRM
- Code letter for the selected Rockwell method
- Code letter for Rockwell hardness
- Hardness value

Advantages
+ covers a large material range (hardness range)
+ a greater hardness range can be covered through variants with different ball diameters and test loads
+ suitable for hardness testing even under unsuitable conditions
+ devices for hardness tests on metals can be used in principle
+ the only standardised ball indentation hardness test method that records solely the remaining deformation portion

Disadvantages
- no comparison of test results that have been gained through different scales
- the methods are little used in comparison to others

Zwick / Roell

2.2.2 Tabular summary: Hardness tests on plastics

Method	Abbreviation	Indentor	Test pre-load/Load application force	Test total force/Spring force	Measurement quantity/range	Test standard
Ball indentation						
	H	Ball, Ø 5 mm	9,8 N	49...961 N	0,15 mm ≤ h ≤ 0,35 mm	DIN EN ISO 2039-1
Shore hardness						
Shore A	Shore A	Truncated cone, opening angle 35°	12,5 N	8,065 N	10 ≤ Shore A ≤ 90	DIN 53505 ASTM D 2240 ISO 868
Shore D	Shore D	Cone Opening angle 30°	50 N	44,5 N	30 ≤ Shore D ≤ 90	DIN 53505 ASTM D 2240 ISO 868
Shore B	Shore B	Cone Opening angle 30°	1 kg	8,065 N	10 ≤ Shore B ≤ 90	ASTM D 2240
Shore C	Shore C	Truncated cone, opening angle 35°	5 kg	44,5 N	10 ≤ Shore E ≤ 90	ASTM D 2240
Shore D0	Shore D0	Ball, dia. 3/32 inch	5 kg	44,5 N	10 ≤ Shore D0 ≤ 90	ASTM D 2240
Shore 0	Shore 0	Ball, dia. 3/32 inch	1 kg	8,065 N	10 ≤ Shore 0 ≤ 90	ASTM D 2240
Shore 00	Shore 00	Ball, dia. 3/32 inch	0,4 kg	1,10853 N	10 ≤ Shore 00 ≤ 90	ASTM D 2240
Ball indentation hardness of soft rubber						
Micro	IRHD Micro	Ball, Ø 0,4 mm	0,235 N	0,1533 N	35 ≤ Micro IRHD ≤ 98	DIN 53519-2 ISO 48 ASTM D 1415
Macro method H	IRHD H	Ball, Ø 1,0 mm	8,3 N	5,7 ± 0,03 N	85 ≤ IRHD H ≤ 100	ISO 48
Macro “normal” N	IRHD normal	Ball, Ø 2,5 mm	8,3 N	5,7 ± 0,03 N	30 ≤ IRHD N ≤ 100	DIN 53519-1 ISO 48 ASTM D 1415
Macro “soft” L	IRHD L	Ball, Ø 5 mm	8,3 N	5,7 ± 0,03 N	10 ≤ IRHD L ≤ 35	DIN 53519-1 ISO 48 ASTM D 1415
Rockwell						
Scale R	HRR	Ball, Ø 12,7 mm (1/2 inch)	98,07 N	588,4 N	0 ≤ HRR ≤ 115	ASTM D 785
Scale L	HRL	Ball, Ø 6,35 mm (1/4 inch)	98,07 N	588,4 N	0 ≤ HRL ≤ 115	ASTM D 785
Scale M	HRM	Ball, Ø 6,35 mm (1/4 inch)	98,07 N	980,7 N	0 ≤ HRM ≤ 115	ASTM D 785
Scale E	HRE	Ball, Ø 3,175 mm (1/8 inch)	98,07 N	980,7 N	0 ≤ HRE ≤ 115	ASTM D 785
Scale K	HRK	Ball, Ø 3,175 mm (1/8 inch)	98,07 N	1471,0 N	0 ≤ HRK ≤ 115	ASTM D 785
Scale α	HRα	Ball, Ø 12,7 mm (1/2 inch)	98,07 N	588,4 N	-100 ≤ HRα ≤ 120	ASTM D 785

Table 3: Overview of test standards andmethods for plastics

Zwick / Roell

2.3 Hardness tests on special materials

Hardness tests on special materials are basically carried out with a modified Rockwell method. The test loads and the indentor geometry, as well as the range of application as listed in tables.

Method	Abbreviation	Indentor	Test pre-load	Test total force	Test standard	Range of application
Rockwell hardness with carbon materials	HR 10/20 HR 10/40 HR 10/60 HR 10/100 HR 10/150	Hardened ball, Ø 10 mm (5 mm)	98,07 N	196,1 N 392,2 N 588,4 N 980,7 N 1471 N	DIN 51917	Carbon-, graphite-, metal-graphite-materials (carbon brushes)
Indentation method on carbon brushes	HR 10/20 HR 10/60 HR 10/100 HR 10/150	Hardened ball, Ø 10 mm	98,07 N	196,1 N 588,4 N 980,7 N 1471 N	DIN IEC 413	Natural/Metal/Electro- graphite, hard carbon
Hardness tests on construction gypsum	H in MN/m²	Ball, Ø 10 mm	10 N	200 N	DIN 1168-2	Plaster gypsum
Indentation test on asphalt	-	Cylinder L = 30mm dia. 11,3 mm dia. 25,2 mm	25 N	525 N	DIN 1996, part 13	Melted/Rolled asphalt
Indentation tests on elastic floor surfaces	- -	Cylinder dia. 11,3 mm dia. 15,97 mm	 3 N -	 500 N 1000 N	DIN EN 433	Elastomers, embossed materials Cork

Table 4: Overview of test standards and methods for special materials

2.4 Hardness tests on ceramics and glass

The hardness of ceramics and glass is basically carried out with the static **method** of the metal hardness test, the scleroscope hardness method is used.

The static methods usually use a diamond indentor and low test loads as these brittle materials tend to propagate cracks. Optical measuring of the small indentations is often made more difficult owing to the poor contrast. Thus the methods with indentation measurement, especially the universal hardness test, have considerable advantages. These have been explained in detail in chapter 2.1 (hardness tests on metals).

Fig. 8: The ZHU0,2/Z2,5 is used for tests on glass

Zwick Roell

3. Hardness testing machines and hardness testers

3.1 Hardness testing machines for metals and plastics

Hardness testing machines result from the combination of Zwick materials testing machines with different accessories for hardness tests and the test software *testXpert®*. Load is applied and controlled by the test machine and the test software *testXpert®*. The hardness testing machines have, as standard, digital measurement and control technology to enable high precision reproducibility of test sequence parameters. Optimisation possibilities of the single test cycles are of great importance especially for automatisation of hardness testing machines. The hardness testing machines provide a guarantee for investment and future security. As the hardness testing machines are based on Zwick materials testing machines, it’s still possible to carry out tensile, compression and flexure tests by simply exchanging the corresponding accessories. The Zwick materials testing machines can be put to universal use. This means that the Zwick materials testing machines that are already in use can also be retrofitted for hardness tests.

Fig. 9: The Vickers hardness testing machine ZHV20/Z2,5

3.1.1 ZHV20/Z2,5 - Vickers hardness testing machine

The **Vickers hardness testing machine ZHV20/Z2,5** is made up by integrating the hardness test device for optical methods (065243.00.X0) and a “zwicki” test machine. The inbuilt load cell permits electromechanically applied test loads between 2 and 200 N. The CCD camera is placed on a microscope angled at 90°. Objective lenses and mounting unit(s) for the indentor(s) are integrated in the revolver head so that position change between setting and measuring the indentation takes place by rotating the revolver. The revolver head is equipped with four stations; i.e. two indentors and two objective lenses can also be combined.

A *testXpert®* master test program (069021.00.X0) contains series tests to Vickers, Knoop and Brinell. Optional expansions are available for selection for automatic indentation measurement and focussing, as well as for hardness sequence tests with manual or motorised compound tables.

Most important **performance characteristics** are:

- flexible adaptation of test parameters, e.g. approach and test speeds,
- manual/automatic indentation measurement,
- selectable 5%-diagonal monitoring,
- selectable pre-control of the sequence position,
- selectable automatic focussing at each indentation and
- freely definable importable and exportable sequence tests, can be used for all methods.

Accessories (option) for ZHV20/Z2,5:

Objective lens mounting device for indentors	
Objective lenses	(50x, 100x, 200x, 600x)
Indentor:	• Diamond pyramid 136° (Vickers) • Diamond pyramid 172° (Knoop) • HM Ball (1 mm and 2 mm dia.)
Adaption plate for a compound table	
Compound tables:	• manual (50 kg) • manual & digital display & RS232 Interface • controllable via motor
Hardness comparison plates	

3.1.2 ZHU2,5/Z2,5 - Universal hardness testing machine

The **universal hardness testing machine ZHU2,5/Z2,5** can be setup on a Zwick materials testing machine by mounting the hardness measurement head (065240/1.00.00), and by the test software *testXpert*®.

A digital travel measurement system (resolution 0,04 µm), a load cell (ranges: 2 N tos 200 N or 5 N to 2500 N) and an interchangeable indentor with measurement transducer are integrated in the hardness measurement head.

The hardness measurement head is constructed so that it can be put to use with all Zwick materials testing machines, and for automation. On the whole the hardness measurement head embraces all hardness tests with indentation depth measurement.

- Universal hardness HU macro range,
- Rockwell hardness scales A to K, N, T, as well as HMR5/250,
- Rockwell hardness scales R, L, M, E, K, α,
- Ball indentation hardness H,
- Vickers depth measurement HVT and
- Brinell depth measurement HBT

Fig. 10: The Universal hardness testing machine ZHU2,5/Z2,5 without optics unit

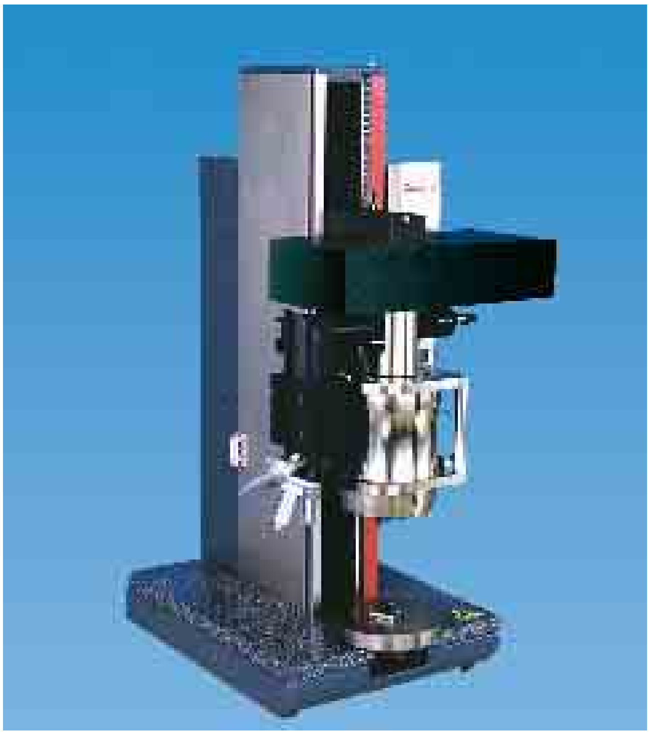


Fig. 11: The Universal hardness testing machine ZHU2,5/Z2,5 with supplementary unit “Optic”

The instrumented hardness test for determining the universal hardness HU is currently standard in pr DIN EN ISO 14577-1 and in DIN 50359-1 for metals. The idea behind these **standards** is to determine a universal hardness scale that covers all hardness grades from rubber right up to very hard metals, and thus enabling better comparibility of material behaviour. Owing to the above, it can be assumed that standards that include plastics, elastomers and rubber will appear in the future.

The force-indentation depth curve, as well as different sequences of the load application procedure enable further **materials indications** without destroying the test body:

- plastic and elastic portions of the indentation energy,
- plastic hardness,
- indentation modulus,
- creep behaviour,
- relaxation behaviour and
- universal hardness.

Some **performance characteristics**:

- one-button operation,
- quick and automatic approach, also for different specimen heights,
- automatic test sequence and evaluation,
- shortest possible test durations,
- universal, material dependent application for practically all hardness methods with indentation depth measurement,
- minimum retrofit time when changing the method and when changing the indentor and transducer foot,
- high accuracy and reproducibility of the test data through high test data resolution and constant test conditions,
- determination of additional material characteristics from the force-indentation depth sequence,
- versatile result display: single and statistical values, graphics, screen display and expressions are pretty well freely changeable,
- multiple curve for direct comparison of the tests of a series,
- configuration of Customised test sequences: even special test sequences can be easily defined and carried out,
- can be used for tests during production.

A **supplementary unit "Optic"** (065242.00.00) has been designed for the hardness measurement head. This unit consists of a measurement microscope with up to 4 objective lenses and a linear slide unit that permits the position between the measurement microscope and the loading assembly to be changed. Thus guaranteeing that a component to be tested must not be shifted.

The universal hardness testing machine ZHU2,5/Z2,5 can, in this constellation, be used to carry out Vickers, Knoop and Brinell hardness tests to test standards in addition to the above mentioned test methods. The combination of supplementary unit "Optic" and hardness measurement head leads to extraordinary properties via the intelligence of *testXpert*®.

Special **advantages** of this configuration are:

- flexible adaptation of test parameters, e.g. approach speeds, test speeds and load removal speeds,
- testing for HU and HV at one indentation,
- the display and evaluation of the test load-indentation depth sequence for all test methods,
- the optical check of the specimen surface,
- the sequence tests are freely definable, they can be imported and exported, this can be used for all methods,
- any sequence tests can be carried out in addition to Vickers hardness sequence tests,
- the performance characteristics when using the "optical" hardness test methods.

The *testXpert*® master test program (069014.00.X0) which was developed for the hardness measurement head enables hardness tests corresponding to the universal hardness, the Rockwell and the ball indentation hardnesses as well as the methods HVT and HBT. This can be expanded for Vickers, Knoop and Brinell hardness tests. In addition, hardness sequence tests with automatic indentation measurement and focussing can be carried out.

Accessories (option) for ZHU2,5/Z2,5

Indentor & measurement transducer:

- diamond pyramid 136° (universal hardness, Vickers)
- diamond pyramid 172° (Knoop)
- diamond cone 120° (Rockwell)
- balls: HM dia. 1/16", steel dia. 1/8", HM dia. 1/4", HM dia. 1/2" (Rockwell)
- ball: steel dia. 5 mm (ball indentation)
- HM balls: dia. 10/5/2,5/2/1,25/1 mm (Brinell)

HU Accessories for tests on balls (dia. 5...10 mm, 10...25 mm)

Supplementary unit "Optic" for the hardness measurement head

Objective lenses (50x, 100x, 200x, 400x, 600x)

Diamond table

Adaption plate for a compound table

Compound tables
- manual (50 kg, 100 kg)
- manual & digital display & RS232 interface
- controlled by motor

Hardness comparison plates

3.2 Hardness testers for metals and plastics

The Vickers and Rockwell hardness testers cover different load ranges and offer equipment in different stages of comfort. Thus the most suitable tester is available for each type of application

3.2.1 Zwick/ZHV - Vickers hardness testers

Zwick/ZHV 10

The **Vickers hardness tester Zwick/ZHV 10** has proven itself especially in the determination of the

- Vickers hardness,
- Knoop hardness,
- Brinell hardness,
- case hardening, hardening and nitride hardening depth
- as well as the scratch hardness (3212001).

Loading weights from 0,2 kg to 10 kg (or up to 30 kg), and interchangeable objective lenses for different magnifications and picture ranges are available for both variants:

- For the **analogue tester** (3212001) the hardness value is evaluated via hardness tables.
- The **PC model** (3212003) works with the test software *testXpert*®, which is, for example, distinguished by simple operation and flexible adaptation of changing test conditions. The indentation is measured on the monitor by placing the measurement lines manually or automatically to the indentation, and is automatically evaluated. A master test program (069021.00.X0) for Vickers, Knoop and Brinell hardness testing for series measurements is available, this program can be expanded by hardness sequence tests and automatic indentation measurement. A wide palette of further accessories is available in addition to manual compound tables.

Fig. 12: The Vickers hardness tester Zwick/ZHV 10 (left: Analogue version, right: PC version

Accessories (option) for Zwick/ZHV 10
- Objective lenses
- Indentor (Vickers, Knoop, Brinell, Rockwell)
- Device for tests in the micro/macro ranges
- Manual compound table
- Clamping devices for tools, round specimen, sheet metal, flat specimen
- Parallel vice, quicker action vice
- Mounting for cogwheels Prisms for round specimen
- Hardness comparison plates

Zwick/ZHV 30 and Zwick/ZHV 50

The **Vickers hardness testers Zwick/ZHV 30** and **Zwick/ZHV 50** covers test loads between 9,8 N and, and up to, 490 N and serves to carry out tests to

- Vickers hardness and
- Brinell hardness (optional).

Fig. 13: The Vickers hardness testers Zwick/ZHV 30 (left) and Zwick/ZHV 50 (right); the testers differ to the extent of their load stages, the type of load change and some software functions

The devices are distinguished by weight loading, by automatic test cycle and indentor holding for most flexible test positions, and are available with LCD line display or with touchscreen. Load changing is via the lateral rotary knobs for the Zwick/ZHV 30 (fig. 13 left), and automatically, via software input, for the Zwick/ZHV 50 (fig. 13 right). The measurement microscope is equipped with shiftable measurement beams, the diagonal value is transmitted to the software at the touch of a button, and the hardness value is automatically displayed on the display. Conversions according to test standards and statistical evaluations are possible in addition to the input of tolerance limits. The standard scope of supply contains a wide range of accessories (indentors, support tables, hardness comparison plates) in addition to an RS 232 interface. The test results can be sent direct to a printer via the RS 232, or can be linked and accordingly further processed and archived in *testXpert*® via test program (069020.0X.X0).

Accessories (option) for Zwick/ZHV 30 and Zwick/ZHV 50
- Indentor (Brinell)
- Hardened, round support table (225 mm dia.)
- Prismatic support table, w.o./with self levelling (up to 6 mm/30 mm)
- Specimen mountings for components, w.o./with self levelling
- Hardness comparison plates

Zwick/ZHU 187,5
The types of the **Universal hardness tester Zwick/ZHU 187,5** cover test loads from 29,4 N up to and including 1839 N, and serve to run the following tests

- Vickers hardness (Macro range)
- Brinell hardness (up to 1839 N)
- Rockwell hardness (classical methods)

Fig. 14: The Zwick/ZHU 187,5 universal hardness tester is available in a range of designs and for a range of different test load combinations

The devices are distinguished by weight loading, by automatic test cycle and indentor holding for most flexible test positions, and are available with LCD line display. Load changing takes place via laterally arranged rotary knobs and the test method selection takes place via the line display. The measurement microscope is equipped with shiftable measurement beams, the diagonal value is transmitted to the software at the touch of a button, and the hardness value is automatically displayed on the display. Conversions according to test standards and statistical evaluations are possible in addition to the input of tolerance limits. The standard scope of supply contains a wide range of accessories (indentors, support tables, hardness comparison plates) in addition to an RS232 interface. The test results can be sent direct to a printer via the RS232, or can be linked and accordingly further processed and archived in *testXpert®* via test program (069020.0X.X0).

Accessories (option) for Zwick/ZHU 187,5
Hardened, round support table (225 mm dia.)
Prismatic support table, w.o./with self levelling (up to 6 mm/30 mm)
Specimen mountings for components

3.2.2. Zwick/ZHR - Rockwell hardness testers
The **Rockwell Zwick/ZHR** hardness testers cover the

- classical Rockwell methods; Zwick/ZHR 4150 (pre-load 10 kg; test load: 60; 100; 150 kg), scales A B C D E F G H K L M P R S V,
- super Rockwell methods; Zwick/ZHR 4045 (pre-load: 3 kg; test load: 15, 30, 45 kg), scales N T W X Y, or
- combinations of Rockwell and Super Rockwell methods; Zwick/ZHR 8150 (pre-load: 3, 10 kg; test load: 15, 30, 45, 60, 100, 150 kg), scales A B C D E F G H K L M P R S V N T W X Y.

Fig. 15: The Zwick/ZHR 4150AK for simple test tasks

Furthermore the devices are available in **different degrees of operator comfort**:

- models with one button operation for simple test tasks (types AK, Typ BK),
- models with line display and integrated conversion functions for standard applications (type LK) and
- models with touchscreen, expanded functions and high operational comfort for comprehensive test tasks. They are put to use for testing batches (type SK), and for production control (type TK).

The modular system of these hardness testers with its range of different equipment enables the Rockwell hardness testers to be equipped corresponding to the application on hand.

Zwick / Roell

Fig. 16: The Zwick/ZHR 8150LK for series tests with small batch sizes

The Rockwell Hardness testers are distinguished by an indentor mounting for hardness tests at measurement locations that are difficult to access, and guarantee **simple operation** via

- automatic test cycle,
- automatic load application and load removal,
- automatic evaluation inclusive of evaluation,
- selection of the loading weight via a rotary knob or via a touchscreen (automatic load change).

The **Rockwell hardness testers** also have

- robust construction with play-free, ball lead screws,
- test area up to 292 mm height for tests on large components,
- input of tolerance preselections,
- RS 232 interface as standard, and
- a range of standard accessories (indentor, support table, hardness comparison plates).

The test results can be sent direct to a printer via the RS 232, or can be linked and accordingly further processed and archived in ***testXpert®*** via test program (069020.0X.X0).

Accessories (option) for Zwick/ZHR
Indentor normal/short (120° diamond pyramid;
balls: dia. 1/16”, dia.1/8”,dia.1/4”,dia.1/2” (Rockwell))
Hardened, round support table (225 mm dia.)
Prismatic support table, w.o./with
self levelling (up to 6 mm/30 mm)
Specimen mountings for components, w.o./with
self levelling
Retainer
Hardness comparison plates

3.2.3 Zwick 3106 – Ball indentation hardness tester

The **Zwick 3106 hardness tester** can be put to universal use for all hardness tests with depth measurement. The following can be tested to standard:

- Rockwell hardness (EN 10109-1, EN ISO 6508),
- Rockwell hardness with carbon materials (DIN 51917, DIN IEC 413),
- Ball indentation hardness of plastics and hard rubber (ISO 2039-1),
- Hardness tests on gypsum (DIN 1168-2),
- Indentation tests on asphalt (DIN 1996-13),
- Indentation tests on resilient floor coverings (DIN EN 433).

The Zwick 3106 hardness tester is equipped with a digital dial gauge, and can be equipped for data output to printer and PC (*testXpert®* 069020.0X.X0). The hardness tester is put to use in research, development, quality control and in goods received tests.

Accessories (option) for Zwick 3106
Indentor normal/short (120° diamond pyramid,
balls: dia. 1/16”,dia.1/8”,dia.1/4”,dia.1/2” (Rockwell)
Indentor (balls, dia. 5/10 mm;
compression die, dia. 11,3/25,2/15,97 mm)
Round support table (dia. 9/48/155 mm)
Hardness comparison plates

Fig. 17 The Zwick 3106 – The ball indentation hardness tester from Zwick

3.2.4 Portable hardness testers

The test piece cannot be brought to the test station when testing large components, a test on site is carried with a portable hardness tester.

Sclerograph

The portable **Sclerograph** is based on the dynamic method of using the rebound height to measure the degree of hardness of the specimen. The analogue hardness tester that can be put to use for hardness determination on steel, non-ferrous metals and rubber. Once the rebound height has been read from the scale you can take the hardness value from the supplied comparison tables. This contains the Shore D, Rockwell B and C as well as Brinell hardnesses.

Fig. 18: The portable sclerograph

Webster Portable hardness tester

Portable, easy to operate hardness tester with inbuilt indentor and load spring. Press the grips together to force the indentor into the specimen (material thicknesses: 0,6 mm ... 8 mm) via the test spring, and the indentation depth is shown on the scale. The value read-off can be converted to Rockwell hardness via the supplied conversion tables. This hardness tester is used for testing the hardness of aluminium, aluminium alloys, brass, copper alloys and steel in the range of E20 up to max. E110.

Fig. 19: The Webster Portable hardness tester

3.3 Hardness testers for plastics and rubber

3.3.1 Analogue hardness testers to Shore

The **hardness testers Zwick 3114...7** correspond to the requirements of test standards DIN 53505, ASTM D 2240, ISO 868 and NFT 51109. These hardness testers can be supplied with or w.o. drag pointers. The testers with drag-pointer make testing at poorly accessible places easier as the measured value is displayed via the drag-pointer and can be read-off at a later moment in time.

Soft rubber, elastomers and natural rubber (10 to 90 Shore A) are tested to Shore A (Zwick 3114/15).

Harder elastomers, plastics and rigid thermoplasts (30 up to 90 Shore D) are tested to Shore D (Zwick 3116/17).

Fig. 20: The Zwick 3114 (Shore A) and Zwick 3116 (Shore D)

The **Zwick 3110...3 hardness testers** correspond to the requirements of test standard ASTM D 2240 and are available with or without a drag-pointer.

They are put to use for hardness tests on

- soft elastomers and textile fabrics (Shore 0, Zwick 3110),
- foam/sponge/cellular rubber (Shore 00, Zwick 3111),
- elastomers harder than Shore A (Shore B, Zwick 3112),
- middle hard elastomers (Shore C, Zwick 3113).

The **Zwick 3370...90 Densimeters** are equipped with a spherical or cylindrical indentor and flat or concave contact surfaces. They have a contact pressure and spring characteristic similar to Shore A. Densimeters are suitable for hardness tests on yarn and thread bobbins, steering wheels, foam and sponge rubber.

The **sausage hardness tester** represents a modified analogue Shore A hardness tester. The indentor is cylindrically shaped with an area of 1 cm^2. This tester is especially suitable for quality control of sausages.

Test device with loading weight (option)
The Zwick 7206 test device is suitable for analogue and digital Shore hardness testers. Hardness tests with test stands ensure positioning of the hardness tester at an exact right-angle with respect to the specimen surface, and thus lead to considerably less test data scatter. Test stands are recommended for use in laboratories as the repeatability of the test method is considerably increased by elimination of operator influence. The Zwick 3114...7 testers as well as the Zwick 3140/1 can be integrated. The test device consists of a stand and a height adjustable head piece with mountings for the tester and the loading weight.
The hardness testers are fixed to the mounting and are aligned via the ball joint so that the hardness tester's contact area is parallel to the specimen surface. Interchangeable loading weights, that are trimmed to 10 N, 12,5 N, and (optional) 50 N test load, ensure a uniform, constant pressure.

Fig. 21: The Zwick 3114 with test stand

Fig. 22: The digital Shore hardness tester Zwick 3140

Control device (option)
The Zwick 7507 control device serves to monitor the spring characteristics of hardness testers to Shore A and D, and for the Zwick 3114 ... 3117 testers as required by test standards. It consists of a stand, a mounting for the hardness tester and a loading unit. The loading unit consists of a lever and notches, and slide and tare weights.
Once the device has been tared, the spring characteristics and friction values of the Shore A hardness tester can be checked in steps of 10 Shore hardness units.
Supplementary weights are required and available for monitoring Shore D hardness testers. Furthermore, a control rings (H04.7507.081) that enables the indentor travel at 40 Shore hardness units to be checked.

Further accessories (option)
Calibration certificate

3.3.2 Digital hardness testers to Shore

The Zwick 3140/1 (Shore A or D) hardness testers serve to determine the hardness of natural rubber, elastomers, plastics and rubber to DIN 53505, ISO R 868, NFT 51109, ASTM D 2240 and BS 903 Part A26 as required by test standards. Determination of the hardness value after dwell times of 3 seconds (to DIN) and 1 second (ISO) can be considered with digital hardness testers. The hardness testers consist of a handy, cylindrically shaped measurement head with indentors for the different Shore hardness scales and a digital electronics unit; a storage case and a power connection unit belong to the scope of supply. The low weight, the handy dimensions and the accumulator operation enable mobile use as well as laboratory operation (test direction as option). The compression spring is integrated in the measurement head in such a manner that the contact ring permits exact parallel contact of the hardness tester with respect to the specimen in any direction of measurement. Prequisite for tests to test standard are specimen with plane parallel contact areas of at least 35 mm dia. and a minimum thickness of 6mm.

Measurement heads
to Shore A or Shore D (DIN 53505, ISO R 868, NFT 51109, ASTM D 2240 and BS 903 part A26),
to Shore B, Shore C, Shore 0, Shore 00, Shore D0 (ASTM D 2240),
for Densimeters with dias. 2,5 and 5 mm (not standardised).

Electronics unit
The micro-computer controlled digital electronics unit is equipped with a serial interface. The software permits buffer storage of up to 2000 values, acceptance of measurement rows as well as further processing of the test data and statistics via a printer or PC. Further processing and archiving of test data is available in test program *testXpert*® (069020.0X.X0).
The 2-line LC-display provides information on the measurement procedure, the measurement row, the test result and the number of saved measured values. All changeable, and the most important statistical parameters are shown on the display.

Accessories (option) for Zwick 3140/1
Test stands
Control unit
Prisms for testing rubber rollers
Calibration certificate

3.3.3 Digital IRHD hardness testers

The **digital IRHD hardness testers** are available in twobasic stages:
- IRHD Micro Compact hardness tester (Zwick 3103),
- Combined IRHD/Shore hardness tester (Zwick 3105 - motorised).

The digital hardness testers serve to determine the hardness tests to IRHD (and Shore) on plastics and rubber. Requirements for IRHD hardness tests to DIN 53519, ISO 48, ASTM D 1415, NFT 46003, BS 903, part A26, as well as for Shore hardness tests to DIN 53505, ISO 868, ASTM D 2240, NFT 51519 and BS 903, part A26 are fulfilled. The hardness tester enables reliable IRHD/Shore hardness tests on O-rings and on shaped parts to be carried out. Furthermore, hardness tests can be reliably carried out on parts with uneven, curved or inclined surfaces as well as in cavities.

IRHD Micro Compact hardness tester (Zwick 3103)
The hardness tester **IRHD Micro Compact/Zwick 3103** consists of a basic casing with integrated electronics and display, a height adjustable support table for the specimen and a column with an inbuilt IRHD micro (DIN 53519-2) measurement device.

IRHD/Shore hardness tester (Zwick 3105 - motorised)
The **IRHD/Shore hardness tester Zwick 3105** - motorised can be activated with two integrated measurement devices, e.g. for Shore A and IRHD micro, that are arranged at an offset of 180° to one another. The required measurement method is activated via the electronic unit's soft touch keyboard.

Fig. 23: IRHD Micro Compact hardness tester (Zwick 3103)

Fig. 24: The motorised IRHD/ Shore hardness tester Zwick 3105

Measurement devices to test standards:
- IRHD micro: for material thicknesses of 0,5 mm to 5 mm, often put to use for tests on 0-rings
- IRHD method H: for harder materials with a material thickness > 2 mm
- IRHD "normal", N: for material thicknesses from 6 mm onwards
- IRHD "soft", L: for material thicknesses from 10 mm onwards
- IRHD "super soft" (not standardised)
- Shore A: for material thicknesses from 6 mm onwards at tests on soft rubber, elastomers, natural rubber, soft PVC
- Shore D: for material thicknesses from 6 mm onwards at tests on hard rubber, acrylic glass, polystyrene, rigid thermo-plasts

The hardness tester works fully automatically in the measurement ranges IRHD. Thus the test is without operator influence.

The hardness tester has **3 types of operation**:
- Standard operation encompasses series tests.
- The interval operation enables long term measurements whereby information on the material's yield behaviour is gained at constant test load.
- The hysteresis operation serves observation of the load application and removal behaviour of a specimen. This could lead to deriving information on the rubber's ageing, and to optimising the degree of vulcanisation.

Rapid centring device for O-rings (option)
As measurements are almost impossible on O-rings with an IRHD or Shore hardness tester without a fixing device, this test device is equipped with a centring station for O-rings and a magnifying glass for controlling the positioning.

Centring station for rubber hoses (option)
A special device for centring rubber hoses.

Accessories (option) for Zwick 3105
Control unit
Control weights
Calibration certificate
Printer

3.3.4 Other hardness testers

The **Pusey & Jones hardness tester (Zwick 3108)** corresponds to the requirements of ASTM D 531-89 and has been designed especially for tests on rubber rollers and similar test pieces.

Zwick / Roell

3.4 ***testXpert®*** - the intelligent test software

testXpert® is the universal test software for materials, component and function tests. Its range of application stretches from Zwick materials testing machines (tensile, compression, flexure and hardness testing machines) and covers hardness testers, pendulum impact testers, extrusion plastometers, automatic test systems, etc. up to modernisation of test machines of a wide range of models and manufacture.

Tasks and functions

testXpert® controls and monitors:

- verification and retrofitting test machines,
- test or test series preparation,
- running the test,
- evaluation and documentation,
- data management and
- quality management.

The concept of *testXpert®* is therefore a guarantee of highest flexibility, functional safety as well as simple useability. *testXpert®* is distinguished by:

- uniform basis software for all applications,
- modular system for master/standard test programs,
- user support via software tools.

The basis software from *testXpert®* works with a single and uniform basis software for all applications. It accepts the data, user and test program management as well as the communication with the test machine and with other peripheral systems.

Master test programs are predestined for frequent change of tests, or for complex tests. You can do the following with little effort or pre-knowledge:

- create and alter test programs,
- individually style monitor layouts and
- create task specific test protocols.

Standard test programs are optimum for standardised testing of large series with constant test conditions. They are

- intuitive and can be used with only a few inputs,
- tailor made for the respective task,
- oriented to everyday use,
- compliant with standards and
- value for money.

Intelligent software wizards guide you rapidly through all menus and, at the same time carry out consistency tests.

Master and standard test programs have been developed for hardness tests. The **master test program 069021.00.X0** combines the “optical” hardness test methods Vickers, Knoop and Brinell and is designed for series tests.

The indentation is shown on the monitor and is measured by placing measurement lines at the appropriate indentation points (with mouse or automatically). The indentation can be saved as a file. All test and evaluation relevant parameters such as test speeds or 5% diagonal deviation are available in wizards in the usual *testXpert®* manner. Options can be supplied for automatic measurement, automatic focussing and hardness sequence tests (Eht, Nht, Rht).

Any hardness sequence tests (with and w.o. edge distance) can be defined and saved in a simple manner. These once-off defined indentation coordinates of a sequence can be use as required. Fig. 25 shows an exemplary sketch of a possibility for the definition of indentation coordinates.

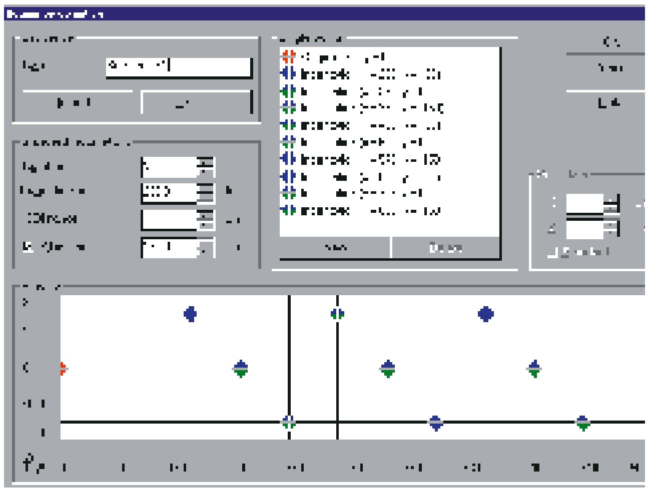


Fig. 25: Definition of indentation coordinates of a hardness sequence in *testXpert®*

The automatic hardness sequence test with a motorised compound table permits, selectively, pre-control of the indentation coordinates and, if necessary, their correction at the click of a mouse in the video frame. Furthermore, all indentations are set automatically and are then measured. When using a manual compound table, the indentation positions are processed sequentially by setting and measuring the respective indentation.

The **master/standard test programs 069014.0X.X0** cover hardness test methods with indentation depth measurement, such as universal hardness, Rockwell hardness (scales A ... K, N, T), ball indentation hardness as well as modified methods HVT und HBT.
The speciality here is that the test load indentation depth sequence is automatically recorded for all test methods. In addition to the hardness value, this sequence can be evaluated for a further description of the mechanical material behaviour. Fig. 26 shows a monitor window with typical data at an HRC series test. The hardness values and the statistical data is automatically calculated and is also automatically transmitted to a test report. A further speciality is that the speeds for approaching the specimen surface at load application and removal are defined exactly and are easy to alter. This master test program can also be expanded for “optical” hardness tests inclusive of hardness sequence tests.

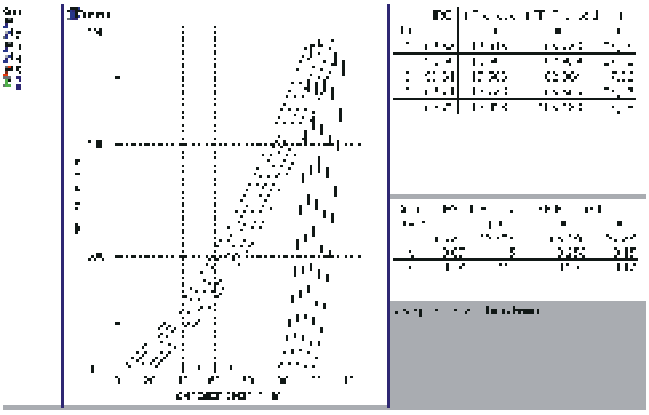


Fig. 26: Monitor window with test load, indentation depth sequences, result and statistics data of a series of Rockwell hardness tests HRC

Test data from different devices can be accepted via the RS 232 interface by way of the **master/standard test programs 069020.0X.X0**.

	ZHU2,5/Z2,5	ZHV20/Z2,5	Zwick/ZHV 10	Zwick/ZHV 30 Zwick/ZHV 50 Zwick/ZHV 187,5	Zwick/ZHR Types 4045, 4150, 8150	Zwick 3106	Zwick 3140 Zwick 3141	Zwick 3105
Master test program (069021.00.X0) for optical hardness test methods (Vickers, Knoop, Brinell)	-	•	•	-	-	-	-	-
Options:								
Automatic indentation measurement (069099.15.X0)	•	•	•	-	-	-	-	-
Automatic focussing (069099.14.X0)	•	•	-	-	-	-	-	-
Hardness sequence tests (069099.13.X0)	•	•	•	-	-	-	-	-
Master/Standard test program (069014.0X.X0) for determination of the universal hardness to DIN 50359-1, the ball indentation hardness and the Rockwell hardness, as well as to the methods HVT and HBT	•	-	-	-	-	-	-	-
Option (069099.12.X0): Optical hardness test methods (HV, HK, HB) for master test program 069014.00.X0	•	-	-	-	-	-	-	-
Master/Standard test program (069020.0X.X0) for accepting test data from different devices via RS 232 C interface (hardness testers, Shore testers, etc.)	-	-	-	•	•	•	•	•

Table 5: Possible combinations of *testXpert®* test programs, and Hardness testing machines and hardness testers

•...can be combined
-...cannot be combined

Zwick / Roell

4 Selection tables

4.1 Selection tables: Hardness testing machines and testers for metals and plastics

Test load		Metals	Plastics	Special materials	Ceramics, glass	Universal hardness	Rockwell A...C	Rockwell N...T	Rockwell L, M, R	Ball indentation h.	HVT, HBT	Vickers Series	Vickers Sequences	Knoop	Brinell	Test software testXpert®	Variations
Hardness testing machines																	
ZHV20/Z2,5[1]	1,96...196 N	•	•	-	o	-	-	-	-	-	-	•	•	•	o	①	
ZHU2,5/Z2,5[1]	4,9...2452 N (1,96...196 N)	•	•	-	•	•	•	•	•	•	•	-	-	-	-	②	
	4,9...2452 N	•	•	-	•	•	•	•	•	•	•	•	•	•	•	②	with supplementary unit “Optic”
Hardness testers																	
Zwick/ZHV 10	1,96...98 (294) N	•	•	-	o	-	-	-	-	-	-	•	•	•	o	①	Analogue device/PC Variant
Zwick/ZHV 30	9,8...294 N	•	•	-	-	-	-	-	-	-	-	•	o	-	o	③	*testXpert®* optional
Zwick/ZHV 50	9,8...490 N	•	•	-	-	-	-	-	-	-	-	•	o	-	o	③	*testXpert®* optional
Zwick/ZHU 187,5	29,43...1839,4 N	•	o	o	-	•	-	-	-	-	-	•	o	-	•	③	*testXpert®* optional
Zwick/ZHR 4150[1]	Pre-load: 98 N Test load: 588,4; 980,7; 1471 N	•	•	-	-	-	•	-	•	-	-	-	-	--	-	③	One button operation, line displ., Touchscreen basic, Touchscreen advanced, *testXpert®* optional
Zwick/ZHR 4045[1]	Pre-load: 29,4 N Test load: 117,7; 264,8; 411,9 N	•	•	-	-	-	-	•	-	-	-	-	-	-	-	③	One button operation, line displ., Touchscreen basic, Touchscreen advanced, *testXpert®* optional
Zwick/ZHR 8150[1]	Pre-load: 29,4; 98 N Test load: 117,7; 264,8; 411,9; 588,4; 980,7; 1471 N	•	•	-	-	-	•	•	•	-	-	-	-	-	-	③	One button operation, line displ., Touchscreen basic, Touchscreen advanced, *testXpert®* optional
Zwick 3106	Pre-load: 3; 10; 25; 98 N Test load: 200; 500; 525; 196,1; 392,2; 588,4 980,7; 1471 N	•	•	•	-	-	•	-	•	•	-	-	-	-	-	③	Loading weights *testXpert®* optional Electronic evaluation unit (digital display, option)
Portable hardness testers																	
Sclerograph		•	-	-	-	-	•[2]	-	-	-	-	•[2]	-	-	•[2]	-	Indentor tip
Webster Portable hardness tester		•	-	•	-	-	-	-	-	-	-	-	-	-	-	-	

Table 6: Tabular listing of hardness testing machines and testers for metals and plastics

• ... extremely suitable
o ... suitable, however limited load range/material dependency
- ... unsuitable

[1] ... can be automated
[2] ... determined to rebound height

testXpert® test programs:
① ... 069021.00.x0
② ... 069014.0x.x0
③ ... 069020.0x.x0

Zwick Roell

4.2 Selection table: Hardness comparison plates

Method	Hardness value approx.
Vickers	
HV 0,05, HV 0,1, HV 0,5	720
HV1, HV 3, HV 5, HV 10, HV 30	240,300,400,540,620,720,840
Rockwell	
HRA	60, 70, 80
HRB	60,80,100
HRC	20, 30, 40, 45, 50, 55, 60, 62/63, 65
HR 15N	70, 80, 90
HR 30N	42, 50, 60, 70
HR 45N	20, 50, 65
HR 15T	80, 91
HR 30T	56, 82
HR 45T	33, 72
Brinell	
HB W1/30	300
HB W2,5/187,5	150, 200, 250, 200, 250, 400, 450
HB W5/750	150, 200, 250, 200, 250, 400, 450, 500, 600

Table 7: Available Hardness comparison plates for the hardness testing machines and testers in table 6

Remarks: The underlined values show the most used hardness comparison plates

Zwick / Roell

4.3 Selection table: Hardness testers for plastics and rubber

Device/Machine	Ball indent. hardn.	Shore	IRHD	Options: Variations		Test standard	Range of application
Hardness testing machines							
ZHU2,5/Z2,5	•					ISO 2039-1	Thermoplasts, duroplasts, hard rubber
Hardness testers							
Zwick 3106							
Zwick 3106	•					ISO 2039-1	Thermoplasts, duroplasts, hard rubber
Shore analogue							
Zwick 3114/5		•(A)		Drag-pointer	②	DIN 53505 ISO 868 ASTM D 2240	Soft rubber, elastomers, natural rubber, PVC soft
Zwick 3116/7		•(D)		Drag-pointer	②		Hard rubber, acrylic glass, polystyrene, rigid thermoplasts
Zwick 3112		•(B)		Drag-pointer	②	ASTM D 2240	Hard elastomers to Shore A
Zwick 3113		•(C)		Drag-pointer	②	ASTM D 2240	Middle hard elastomers and rubber materials
Zwick 3110		•(0)		Drag-pointer	②	ASTM D 2240	Soft elastomers and textile fabric
Zwick 3111		•(00)		Drag-pointer	②	ASTM D 2240	Foam/sponge/cellular rubber
Densimeter 3370/3390					③	Not standardised	Yarn, thread bobbins, foam/sponge rubber Steering wheels
Shore digital							
Zwick 3140		•(A)			①	DIN 53505 ISO 868 ASTM D 2240	Soft rubber, elastomers, natural rubber PVC soft
Zwick 3141		•(D)			①		Hard rubber, acrylic glass, polystyrene, rigid thermoplasts
Zwick 3143		•(B)			①	ASTM D 2240	Hard elastomers to Shore A
Zwick 3144		•(C)			①	ASTM D 2240	Middle hard elastomers and rubber materials
Zwick 3146		•(D0)			①	ASTM D 2240	High strength textile fabrics
Zwick 3145		•(0)			①	ASTM D 2240	Soft elastomers and textile fabric
Zwick 3142		•(00)			①	ASTM D 2240	Foam/sponge/cellular rubber
Densimeter 3347/3349					③	Not standardised	Yarn, thread bobbins, foam/sponge rubber Steering wheels
IRHD							
Zwick 3103			•	Meas. device IRHD micro	④	DIN 53519-2 ISO 48 ASTM D 1415	O-Rings, small and thin materials Soft materials up to 35 IRHD Hard materials from 30 IRHD onwards
Zwick 3105			•	Meas. device IRHD micro IRHD soft IRHD normal IRHD Method H Shore A, B, 0, D	④	DIN 53519-1 ISO 48 ASTM D 1415 ISO 48	O-Rings, small and thin materials Soft materials up to 35 IRHD Hard materials from 30 IRHD onwards Harder materials from 85 IRHD onwards
Pusey & Jones							
Zwick 3108						ASTM D 531	Rubber rollers

Table 8: Tabular listing of the hardness testers for elastomers and plastics, and their assignments and properties

Legends for the options:
① ... test stand, control unit, calibration certificate, software *testXpert®*, prisms
② ... test stand, control unit, calibration certificate
③ ... test stand, calibration certificate
④ ... control unit, calibration certificate, software *testXpert®*, O-ring centring unit, hose centring device