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LEEB HARDNESS-CALIBRATION-MACHINE

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Abstract – For the calibration of hardness reference blocks according to the German standard DIN 50156 - hardness test according Leeb - MPA NRW has realized a new concept of hardness reference standard machine. A laser interferometer is used for the continuous measurement of distance and time. In a post process the speed of the indenter will be evaluated from the measurement data. The conception of the machine, measurement capabilities and the effects of variation of test parameters are reported in the following paper.

Keywords: Leeb-hardness, drop impact test, laser interferometer.

1. BASIC INFORMATION

In the year 2007 the German standard DIN 50156 part 1 to 3 for the hardness test according Leeb was published. Part 3 of the standard describes the quality criteria for hardness reference blocks. In addition, the standard lists the requirements on a Leeb hardness calibration machine for the calibration of hardness reference blocks. The MPA NRW realized for the first time the concept of a hardness calibration machine, which includes the evaluation of velocities from the measurements of distance and time, using laser interferometry.

2. DEFINITION OF HARDNESS ACCORDING LEEB

In the hardness test according Leeb the impact body impacts on a test piece with a certain velocity and rebounds. The hardness number is derived from the ratio of the rebound and impact velocity [1,2]

$$HL = \left| \frac{v_R}{v_A} \right| \cdot 1000 \quad (1)$$

HL – Leeb hardness value

v_A - Impact velocity

v_R - Impact velocity

3. REQUIREMENT ON THE LEEB HARDNESS CALIBRATION MACHINE

The normative requirements according DIN 50156 are the base for the conception of the Leeb hardness calibration machine. The impact energy , the mass of the impact body, the diameter and the material of the impact body are determined. On the portable hardness test machines a spring accelerates the impact body to the appropriate velocity. Contrary to that, the functional principle of a calibration machine or a reference standard machine is based on a – by the gravity field of the earth - constantly accelerated impact body.

Table 1 Symbols, dimension, designations and parameter of the Leeb scales according types of impact device

Designation	Parameters of types of impact devices						
	D/D C	S	E	D+1 5	DL	C	G
Kinetic impact energy [mJ]	11,5	11,3	11,5	11,2	11,2	3,0	90,0
impact velocity [m/s]	2,05	2,05	2,05	1,70	1,75	1,4	3,0
Mass of the impact body [g]	5,45	5,45	5,45	7,80	7,23	3,00	20,00
Radius of the indenter ball [mm]	1,5	1,5	1,5	1,5	1,5	1,5	2,5
Material of the indenter	WC	K	PK D	WC	WC	WC	WC
Hardness of the indenter [HV 2]	1600	1600	5000	1600	1600	1600	1600

The required impact velocity is achieved by the appropriate height of fall with known local “g” (Derivation from the law of energy conservation, see Gl. 2,3 and 4).

$$E_{pot} = m \cdot g \cdot h \quad (2)$$

E – Energy

$$E_{kin} = \frac{m}{2} \cdot v^2 \quad (3)$$

m – Mass

$$h(v) = \frac{v^2}{2 \cdot g} \quad (4)$$

g – gravitational acceleration

h – height of drop

After this principle the measurement system in the MPA NRW is developed. It consists of a down pipe, a laser length measuring system as well as impact bodies, which are equipped with reflectors.

3.1 Length- resp. Velocity Measuring System

The evaluation of the velocity has to be made out of the continuous recording of the time-length-process during the free fall of the impact body. Normatively given is the maximum of the impact velocity on device type “G” with 3m/s. Required is a continuous and non-contact length measuring with a resolution of minimum 0,1HL.

A laser interferometer is used for the length measuring on the base of a He-Ne-laser of the firm SIOS Messtechnik GmbH, which has a stabilized frequency. According to manufacturer’s specifications this uncertainty is under standard laboratory conditions less than , with a maximum measuring range up to 5m and a deviation of the linearity of <2 nm. The resolution amounts 0,1 nm. Standardly the maximum displacement velocity is around 0,8 m/s. This displacement velocity was extended according to the requirements to over 3 m/s (pulse frequency for the recording of the measuring data 10 kHz) [3]. Out of the recorded data the velocity-time-process and the velocity-length-process are calculated.

3.2 Guidance of the impact body

For all standardized Leeb-impact-bodies a down pipe is used. And the length of the down pipe is designed for the impact body “G”. The guidance of the impact body in the downpipe should occur with preferably small air resistance, with small friction and tolerance.

The release of the impact body in the downpipe has to be possible from different drop heights. Instead of a pipe a guidance out of 3 resp. 4 bars is chosen. The advantage of such a guidance consists of the means of access on the impact body and the well air downstream during the drop impact test.

To minimize the effect of the pulse transmission, the mass of the plane table is 150 kg (standardized requirement is a minimum mass of 50 kg). The test plane table and the equipment configuration out of downpipe, length-measuring system, positioner, impact body, release and intercept mechanism are degenerated.

3.3 Height Positioning of the impact body

The requirement on the positional accuracy of the impact body of 0,1 mm, which results in the maximal acceptable deviations of the impact velocities and its reduction to the drop height is achieved by a digital scale. The definite drop height and also the rebound velocity are defined by the analysis of the measuring data of the length-measuring system.

3.4 Requirements on the impact body

The standardized requirements on the impact body and the indenter are dependent on the type of the impact device. The deviations of the rated value of the impact body masses amount maximal 0,1%. The measured deviations of the radius and the circularity of the inserted indenter balls is smaller than 2 µm.

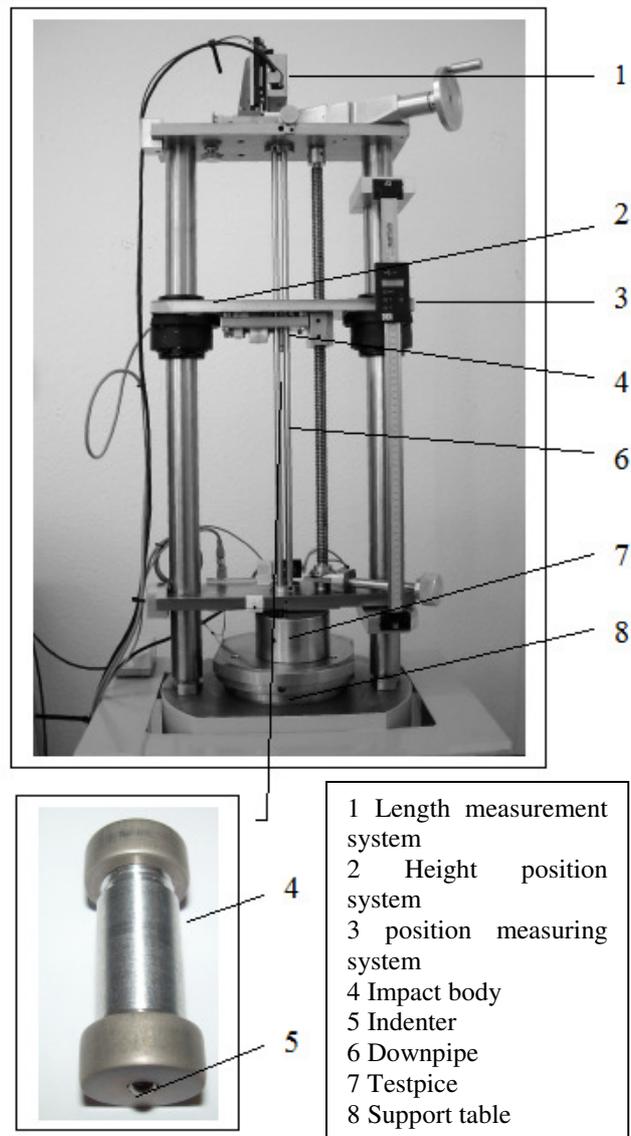


Fig. 1. Hardness calibration machine for the hardness test according Leeb

4. TEST PROCEDURE

The recording of the measuring data will be started by the control electronics. The impact body will be released 0,2 seconds later and falls in free fall in direction of the test piece. A light barrier records the impact of the impact body on the test surface and gives the signal to **intercept** (pneumatically with additional locking lever mechanism) after the first impact. The singular impact of the impact body provides further analysis of the indentation generation (impact diameter, impact depth, **pull up around the indentation**, etc.). A test procedure without **interception** of the impact body is possible as well.

5. DEFINITION OF THE IMPACT VELOCITY AND REBOUND VELOCITY

The impact body achieves the maximum velocity at the impact directly before the contact with the surface and at the rebound at the time of the unbonding of the surface (Fig. 2 and 3). For definition of the impact and rebound velocities the data sets will be evaluated over a linear regression. The theoretical velocity plot results from the measured drop height and the local acceleration of fall. The testing of the procedure, which is appropriate in function, occurs at every test by the comparison of the measuring data with the theoretically calculated data of the length-time-process and the speed-time-process (Fig. 4).

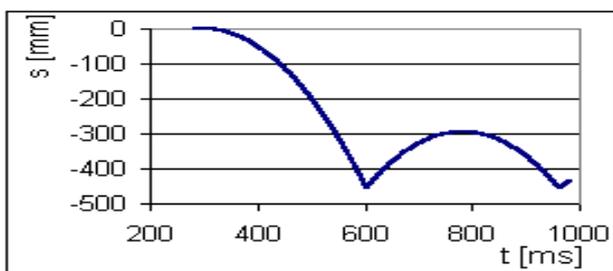


Fig. 2. Distance time diagram from the drop impact test during the Leeb G hardness test

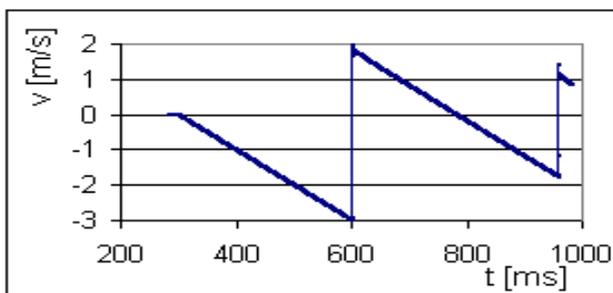


Fig.3. Speed time diagram from the drop impact test during the Leeb hardness test

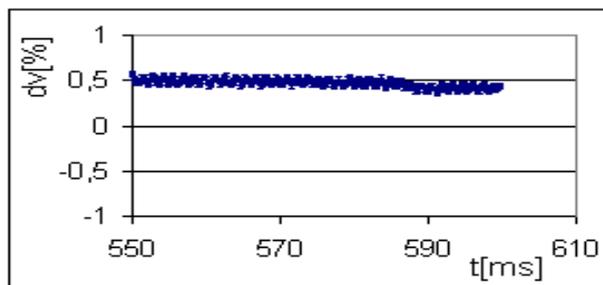


Fig.4. Difference between the speed from the drop impact test and the theoretical

6.EFFECT OF THE PARAMETER ON THE HL-HARDNESS VALUE

Formally the hardness value according Leeb is based on the relation of impact- and rebound-velocity (see Gl.1). The impact velocity is independent on the mass and only given by the drop height. The rebound velocity results from an impulse, which effects the impact body, of the energy of elastic resilience and is dependent on e.g. the mass, the form and the material (E-Modul) of the impact body but the hardness of the test piece. Between the kinetic energy at the impact and the velocity there is a quadratic relation (Gl.2). Between the kinetic energy and the mass there is a linear relation (Gl.3). Introduced are the results from series of measurements with the impact bodies “D” and “G” on hardness reference blocks in the hardness ranges 240,450,600 and 780 HV.

6.1. Impact velocity of the impact body

In series of tests the impact velocities were varied by the analog changes of the drop height by approx. +- 10%. With increasing impact velocity the determined hardness values decreased (Fig. 5) and the impact diameter got bigger. A possible explanation of the measured hardness decrease will be the influence from a diameter off the radio form plastic to elastic energy .

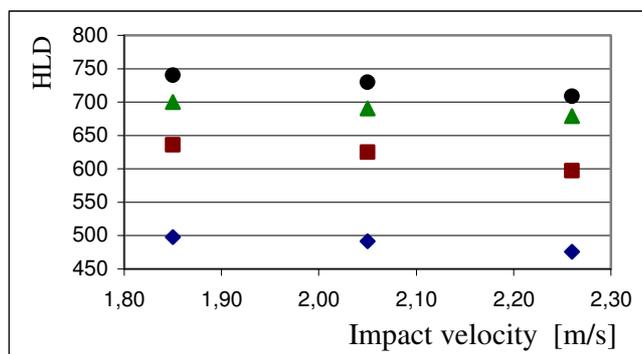


Fig.5: Dependence of the Leeb hardness on the barrier impact velocity (Symbols for the different hardness values ♦ 240 HV, ■ 450 HV, ▲ 600 HV, • 780 HV).

6.2 Mass of the impact body

In the tests the mass was varied by +/-10% of the reference value. With increasing mass the measured HL-hardness-values (Fig. 6) show an increase by simultaneous greater impact diameters. This contradiction shows the material and the form of the impact body as possible further influence quantity.

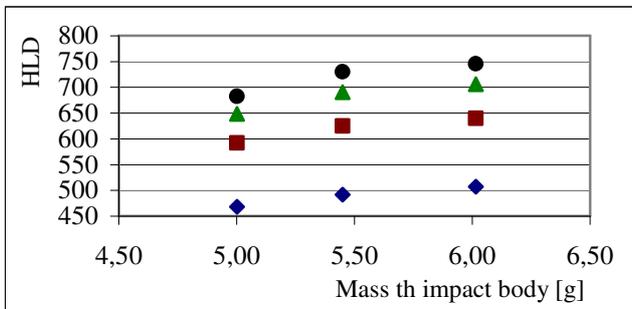


Fig. 6: Dependence of the Leeb hardness on the mass of the impact body (Symbols for the different hardness values ♦ 240 HV, ■ 450 HV, ▲ 600 HV, ● 780 HV).

6.3 Material and form of the impact body

At the impact and the indentation, the test piece and the impact body will be – additionally to the plastic deformation of the test piece – elastically deformed and receive a defined energy. At the rebound this saved elastic energy is set free and accelerates the impact body. (model image of 2 springs). Tests with the impact bodies type “G” of the same mass and length out of steel (st) and Titan (Ti) as well as an also longer Titan impact body (TiL), with the same mass, show a significant influence of material and form on the HL-hardness-values (Fig.7). Because the microscopically measured impact diameters on the probe do not show significant differences (Fig. 8), which was - by the same kinetic energy and with the same impulse of the impact bodies- not expected, the hardness differences are probably based on the spring qualities of the impact bodies (with the more flexible spring less energy is transformed in plastic and more in elastic deformation.)

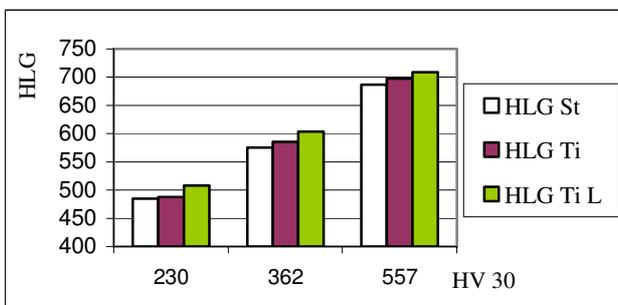


Fig. 7. Dependence of the HLG of hardness values of the impact body

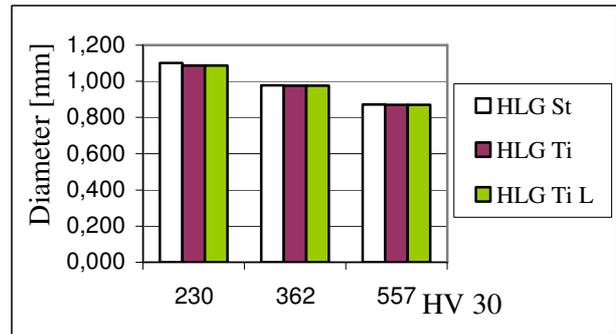


Fig. 8. Dependence of the HLG of hardness values of the impact body

7. ABSTRACT AND PERSPECTIVE

The concept of recording of the drop impact test with a laser length measuring system offers new analysis possibilities of the parameter, which are relevant for the test. Set value deviation of the mass influence the HL-hardness-value stronger than of the impact velocity. With the current sample rate of 10 kHz the indentation process of the impact body cannot be collected metrologically. The theoretical, of Leeb defined, contact times are ca. 0,05 ms [4]. The company SIOS GmbH works currently on the further development of the laser-length-measuring system. The aim is sample cycles at the continuous length-time-measuring of up to 1 MHz. This would allow a further analysis of the impact and rebound process.

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