Using Equotip Hardness Test Blocks

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Abstract

- Section 1 motivates the use of hardness test blocks.
- Section 2 introduces the requirements concerning the verification procedure for Leeb testers and the specifications of hardness test blocks according to standards.
- Section 3 gives an overview over the range of Equotip hardness test blocks.
- Section 4 describes how the daily verification of Leeb instruments is carried out.
- Section 5 summarizes this article.

1. Introduction

For all hardness test methods for metallic materials – and even more generally – the reliability of test results depends on the stability of the measuring device. Due to staining, abrasion or damage of the indenter, misalignment or damage of the instrument mechanics, failure of the sensor system or evaluation electronics or due to other effects, measuring results could change over time, either slowly or abruptly.
In order to detect such changes in due time, it is common to verify the operation of the testing device using calibrated hardness reference blocks. Corresponding national and international standards as well as individually agreed acceptance test procedures demand such checks more or less mandatorily. This also applies to hardness testing according to Leeb, which is standardized in ASTM A956 and DIN 50156 [1,2].
A more general overview over hardness reference material is given in [4].

2. Verification of Leeb hardness testers according to standards

With the launch of the first Equotip Leeb hardness tester by Proceq, a periodic verification of the instrument was introduced analogous to the standard practice in traditional hardness testing. In the two most commonly used Leeb standards, ASTM A956 and DIN 50156, the periodic verification has also been included.

1. <u>Proceq's instructions (since 1975):</u>
   - Proceq recommends considering an instrument as successfully verified when the arithmetic mean value of >3 readings does not differ by more than 6 HL from the reference calibration value. The >3 impacts shall be randomly distributed over the test surface of an Equotip test block.
   - Since 2009, Proceq has been increasingly urging to users to select a test block whose hardness is similar to the expected hardness of the samples under test.
   - Users who conduct the sample test according to a national standard are advised to adhere to the instructions therein for daily verification.
2. <u>ASTM A956 (first published in 1996, revised in 2002 and 2006):</u>
   - The periodic verification is specified in section 7 and described in more detail in sections 13 to 15 of the standard.
   - The instrument shall be verified "prior to each work shift, work period of use, and following a period of extended continuous use (1000 impacts)", as well as when parts of the test equipment are replaced. At least in the latter case, the use of multiple test blocks is strongly recommended: the softest block should be softer than the minimum expected sample hardness, one block hardness should fall well within the expected sample range, and the hardest block should exceed the maximum expected sample hardness.
   - Two impact indentations shall be made on a calibrated Leeb hardness test block. The instrument is successfully verified if neither reading differs from the reference set-point value by more than 6 HL.

3. DIN 50156 (first published in 2007):

- Appendix A of Part 1 (out of 3) deals with the periodic verification.
- For each impact device type, three hardness ranges are specified. For the most common types D and G, these are as follows:

type D	< 500 HLD	500 … 700 HLD	> 700 HLD
type G	< 450 HLG	450 … 600 HLG	> 600 HLG

Tab. 1: Hardness ranges for the daily verification of Leeb impact devices types D and G according to the test standard DIN 50156.

- "The performance check of the instrument should be carried out prior to use on each day the instrument is used, at approximately each hardness level and for each scale that is to be used."
- At least 3 impacts should be made on a calibrated Leeb hardness test block. The instrument is considered as "verified satisfactory" if the arithmetic mean value and the reference calibration value do not differ by more than 15 HL.

From this, it seems ASTM requires a closer matching of the measurement and the "real" value than DIN 50156. However, this is put into a different perspective when considering that DIN refers to certified reference material traceable to a national etalon held by Physikalisch-Technische Bundesanstalt (PTB) in Germany. This fixes the Leeb hardness scales according to DIN 50156. In contrast, the ASTM standard is not based on a standardized national Leeb scale, but test blocks are calibrated with Leeb testers certified by the instrument manufacturers. Different testers may hold systematic deviations between each other that cannot be revealed through checks on the same manufacturer's blocks. Only a test on a genuine Equotip block would permit determination of the bias (and thus the uncertainty) with respect to the inventor's genuine Leeb scale and other manufacturers' in-house standards.

3. Range of Leeb hardness test blocks

The standard specifications of Leeb hardness test blocks in DIN 50156-3 and ASTM A956, section 17 are very similar. The key parameters are listed in Tab. 2.

type of impact device	D/DC, DL, C, S, E / G	
diameter of test block	≥ 90 mm / ≥ 120 mm)	
thickness of test block	≥ 54 mm / ≥ 70 mm)	
roughness of calibrated test surface	ASTM:	$R_a \leq 0.4$ µm
	DIN:	$R_a \leq 0.025$ µm
roughness of other surfaces	ASTM:	$R_a \leq 7$ µm
	DIN:	not specified
homogeneity of calibrated test surface	ASTM:	R[1] < 13 HL
	DIN:	V[2] ≤ 2.0 % (< 450 HL)
		V ≤ 1.5 % (450 to 750 HL)
		V ≤ 1.0 % (> 750 HL)
reference calibration value	average from 10 readings, randomly- and evenly-distributed over the test surface	
two-sided calibration of test block	permitted	

[1] R: range, difference between the lowest and the highest reading out of the 10 readings
[2] V: variation coefficient, standard deviation of 10 readings, divided by their average

Tab. 2: Requirements on Leeb hardness test blocks according to ASTM A956 and DIN 50156-3.

The ASTM homogeneity requirement is generally slightly tighter than the DIN specification.
The most striking difference between Leeb test blocks and blocks for static hardness tests (such as HRC or HB) is the size of the blocks. The larger block size is important as the Leeb method assumes that the dynamic Leeb test impact is carried out on a sufficiently large and heavy sample.

Reference [5] reasons that the range of readings (min/max), or alternatively the variation coefficient, is not a "genuine" measure of the homogeneity of the test block surface. In addition, readings often decrease slightly from the center to the edge of the Leeb test blocks due the measurement principle.

Proceq offers the widest range of Leeb hardness test blocks worldwide.

1. <u>Hardness test blocks of diameter ~90 mm, thickness ~55 mm, weight ~2.8 kg:</u>

impact device type	low hardness range (<225 HV / <220 HB)	mid hardness range (~35 HRC / ~335 HV / ~325 HB)	high hardness range (~630 HV / ~56 HRC)	very high hardness range (~800 HV / ~63 HRC)
D/DC[1)]	< 500 HLD	~600 HLD	~775 HLD	[2,3)]
DL	<710 HLDL	~780 HLDL	~890 HLDL	[2,3)]
C	<565 HLC	~665 HLC	~835 HLC	[2,3)]
S	[2)]	[2)]	~815 HLS	~875 HLS
E	[2)]	[2)]	~740 HLE	~810 HLE

[1)] both two- and one-sided test blocks available
[2)] additional calibration available on test blocks for the other device types
[3)] not recommended for use in this hardness range due to increased wear of impact body

Tab. 3: Proceq's range of Equotip hardness test blocks for the daily verification of Leeb hardness testers types D/DC, DL, C, S and E.

2. <u>Hardness test blocks of diameter ~120 mm, thickness ~90 mm, weight ~6.3 kg:</u>

impact device type	low hardness range (<200 HB)	mid hardness range (~340 HB)
G	< 450 HLG	~570 HLG
D/DC, DL, C, S, E	[1)]	[1)]

[1)] additional calibration available on test blocks for the other device types

Tab. 4: Proceq's range of Equotip hardness test blocks for the daily verification of Leeb hardness testers type G.

Hardness test blocks calibrated by Proceq are supplied along with calibration certificates. The certificates contain the same data as such issued by accredited test laboratories. The calibration procedure is carried out as specified in DIN 50156-3 and ASTM A956. In particular, Proceq's plant-internal primary reference measuring device is identical in construction to the German national standard Leeb measuring device of Physikalisch-Technischen Bundesanstalt (PTB) in Germany and National Institute of Metrology (NIM) in China. In addition, the reference values are engraved in the test surface and quoted on barcode labels on the block circumference.

The validity of Proceq test block certificates is not bindingly limited in time. However, they contain a reference to DIN 50156-3, according to which the validity should be limited to 5 years. In theory, it should be highlighted that the hardness of the material can change with time, particularly when speaking of very hard and very soft material. From experience, however, Equotip hardness test blocks have proven stable even over much longer periods of time provided proper storage.

Supplemental to Proceq's calibration certificate, additional calibrations from accredited institutes are available for Equotip test block surfaces:

- Leeb hardness scales HLD, HLE, HLS and HLG according to DIN 50156-3
- Brinell hardness scale HB according to ISO 6506-3
- Vickers hardness scale HV according to ISO 6507-3
- Rockwell hardness scales HRC, HRB according to ISO 6508-3

The reference measurement equipment used by the accredited institute for these calibrations is traceable to national hardness etalons.

4. How to carry out periodic instrument checks

According to DIN 50156-1, the periodic check of Leeb hardness testers shall be carried out at ambient air temperatures between 10 and 35°C. ASTM A956 limits the test piece temperature to 4 to 38°C. If this is not possible, the user should report the relevant temperature in the test report.

- Remove the protective sticker or alternative corrosion protection from the test surfaces of the hardness test block.
- Carefully clean the test surface with acetone (or any other acid-free non-polar cleaning agent).
- Clean the ball indenter of the impact body with acetone.
- Place the test block on a plane solid support. The support must not move or vibrate during the measurement. A plane and smooth steel plate of at least 200 x 200 mm and a thickness of more than 25 mm is ideally suited. To ensure good contact and avoid scratching of the backside test surface, sandwich a plastic film between support and test block.
- As described further above, a number of Leeb impacts shall be distributed evenly across the test surface. Take care that the distance between the edges of two adjacent indentations exceeds three times the indentation diameter. Otherwise, higher hardness values will be measured: around existing indentations, the material has been cold work hardened [3].

The measurements shall be compared against the reference set-point value as per instructions given in the referred standards.

- If the periodic check fails, carefully clean the impact device with the supplied cleaning brush, and then repeat the check.
- It is recommended to keep records of the results of the check, quoting at least the serial number of the device, the serial number of the test block, the results, the date of the check, and the name of the inspector. In addition, any circumstances should be reported that can have affected the test result (such as an ambient temperature outside the limits specified in the relevant test standard).
- When finished, clean both test surfaces of the block with acetone. Even slight hand perspiration under finger prints may cause rapid corrosion of the surfaces!
- Protect the test surfaces against corrosion (e.g. with protective stickers or acid-free oil).
- Hardness test blocks must be stored in a dry place that does not undergo excessive temperature variations.

With an increasing number of indentations on the surface of a test block, the measured hardness values will increase and scatter more [4]. If there are too many indentations on a surface to adhere to the minimum distance of 3 indentation diameters between indentation edges, the test surface must not be used anymore. Neither must test surfaces be used if they are corroded, (heavily) scratched or have other obvious damages.

Never “recycle” test surfaces by grinding off the upper skin. On the one hand, the hardness may be affected from the machining. On the other hand, remainders of the cold work hardened zones of the ground indentations will lead to higher hardness values and larger scatter of the values. And finally, the block parameters specified in Tab. 2 will not normally be met anymore.

Conclusions

As for any other hardness test devices, the accuracy and stability of Leeb hardness testers should periodically be verified using calibrated Equotip hardness test blocks. The test standards ASTM A956 and DIN 50156 specify the requirements on the hardness test blocks and provide very useful guidelines for instrument checks. Proceq offers a portfolio of Leeb hardness test blocks that covers the requirements of these standards. Also traceability to primary standards is secured.

Periodic instrument checks with Equotip hardness test blocks are pretty much straightforward. When a few simple rules are followed, there should hardly emerge any problems.

For further information please contact your Proceq representative or visit http://www.proceq.com *and* http://www.equotip.com.

References

[1] ASTM A956, *Standard Test Method for Leeb Hardness Testing of Steel Products*, 2006.
[2] DIN 50156, *Metallische Werkstoffe – Härteprüfung nach Leeb*, 2007.
[3] K. Herrmann et al., *Härteprüfung an Metallen und Kunststoffen*, Expert Verlag, 2007.
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[5] T. Yamamoto, M. Yamamoto, K. Miyahara, *Accuracy for Standard Blocks for Hardness and Uncertainty of Hardness*, XIX IMEKO World Congress, 2009.