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TracInd BVK-H

Redefining hardness measurements

22RPT01 TracInd BVK-H Traceability for indentation measurements in Brinell-Vickers-Knoop hardness

Cihan Kuzu, Alessandro Germak, Febo Menelao, Moritz Loewit, Andrea Prato, Anton Štibler, Gianfranco Genta, Jiří Borovský, Giacomo Maculotti, Miha Hiti, Janusz Fidelus, Tatiana Apostol, Šejla Ališić, Belma Fakić, Philipp Reinstädt, Francesco Turotti, Renato Affri, Branka Muminovic, Azmir Alić

TÜBİTAK · PTB Physikalisch-Technische Bundesanstalt National Metrology Institute · INRiM Istituto Nazionale di Ricerca Metrologica · Bundesamt für Eich- und Vermessungswesen · CMI Czech Metrology Institute · IMBIH · Główny Urząd Miar · ZAG · Politecnico di Torino · National Institute of Metrology · Materialprüfungsamt Nordrhein-Westfalen · LTF · EASYDUR Testing Equipment

Introduction

Hardness is an important material property describing a material's resistance to localized deformation from an indenter pressing or scraping against its surface. Hardness is not a physical quantity; it is a method-based quantity and thus the definition of the method and the measurands subject to consideration in hardness are very critical.

Hardness is determined by measuring the indentation size realised on the tested material surface, the measurement is strongly dependent on the image magnification and processing instrument, the operator, and, if used, software [1]. Significant deviations in measurement results among national metrology institutes (NMIs), as well as between NMIs and secondary - and testing laboratories are due to:

- The lack of a physical definition for, nor a common agreement on the location of the border of indentation. Material dependent transition from the undeformed surface to the indentation as material is pushed outside (pile-up) or pulled down (sink-in) complicates the correct border selection.

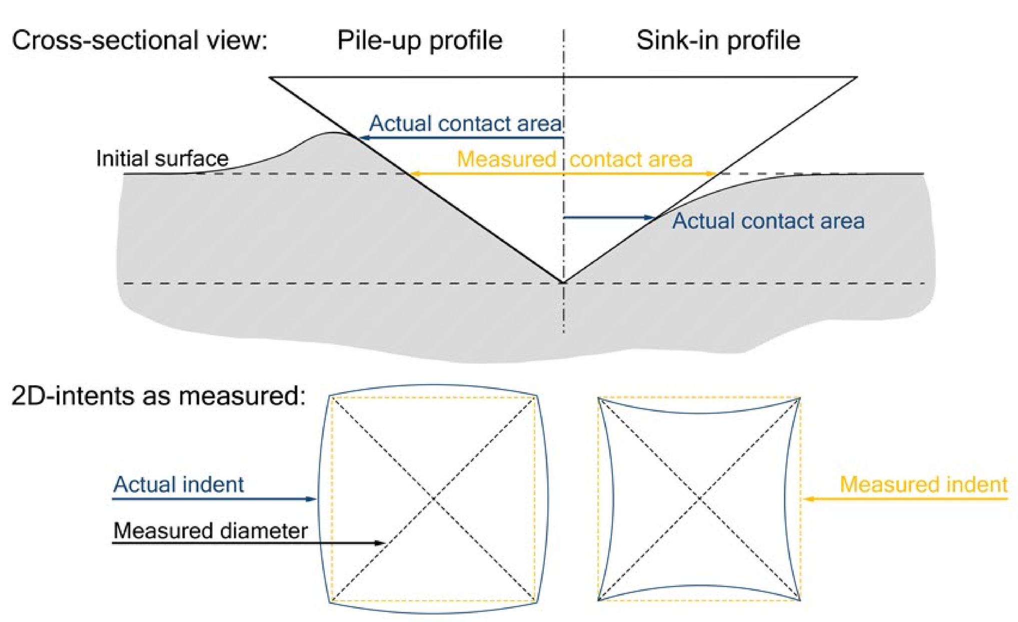

Figure 1: Cross section of an indentation profile showing pile-up and sink-in behaviour and the difference between the actual and measured contact areas

- The lack of specifications and settings for the variety of indentation measurement instruments used throughout the measurement chain. This highlights the lack of standardised measurement methodology and instrumentation, although all instruments used are compliant with relevant ISO hardness standards from a length measurement point of view.

A unified set of definitions and methodology is developed for Brinell-, Vickers- and Knoop hardness scales (BVK).

Experimental base

A total of 76 indentations (36 for Brinell, 24 for Vickers and 16 for Knoop scales) were produced on multiple materials and surfaces and measured multiple thousand times by different NMIs and universities utilizing both conventional optical two-dimensional methods as well as state-of-the art methods like scanning tactile and laser confocal measuring systems to measure the 3D surface areas of the indentations. These indentations and measurements are an excellent representation of the scales and devices most commonly used wordwide.

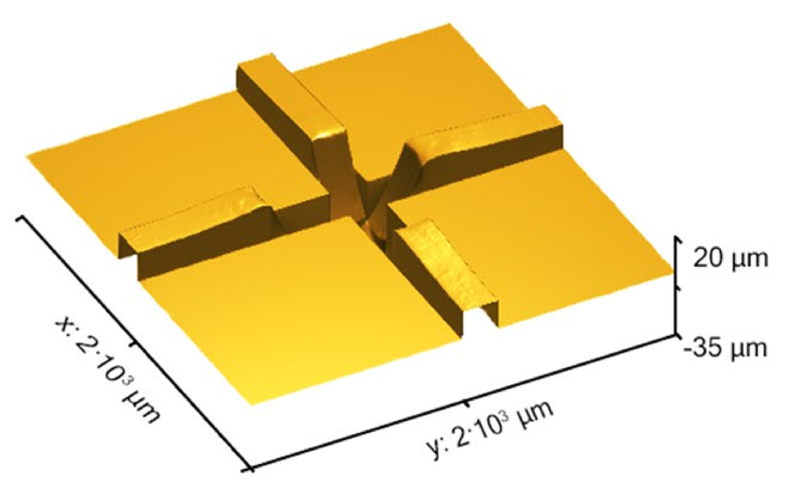

Figure 2: Digital reconstruction of an intentation profile of a 75,26 HBW 2,5/187,5 indent using tactile measurement data used for analysis of indentation profiles and material behaviour

Universal indentation border definitions

3D tactile measurement data allows for an in-depth analysis of the indentation height profile and its relation to the known geometry of the indenter used. From the raw data the slope angle of the indentation as well as the change in slope angle are calculated [2].

Change in the slope angle is used to determine the real contact area. Experiments have shown significant differences between diameters derived from 3D and conventional 2D measurement (0,399% deviation in calculated hardness for the dataset shown in figure 2 and figure 3).

Universal definitions will be based on the 3D measurement data, which in turn is correlated to the 2D measurements usually performed in the laboratories ensuring an easy to establish standard.

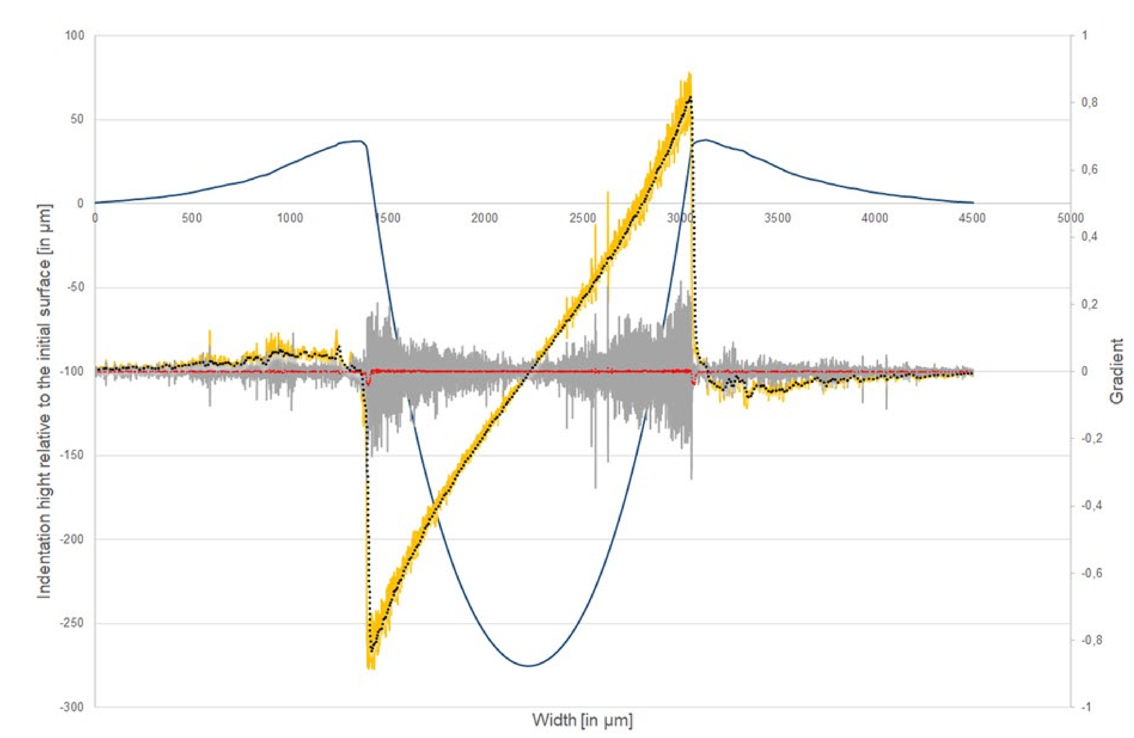

Figure 3: Cross section of the 75,26 HBW 2,5/187,5 indentation profile shown in figure 2 using the tactile measurement data for the calculation of slope angle and rate of change of the slope angle for calculating the actual contact area

Testing methodology

Experimental data show a strong correlation between certain tested influencing factors like the dwell time (e.g. in figure 4) or block surface roughness on the measured hardness value. There is also significant influence of the illuminance and the numerical apertures of the lenses and their relationships on the indentation size for both bright-field and dark-field illumination conditions and for both pile-up and sink-in behavior.

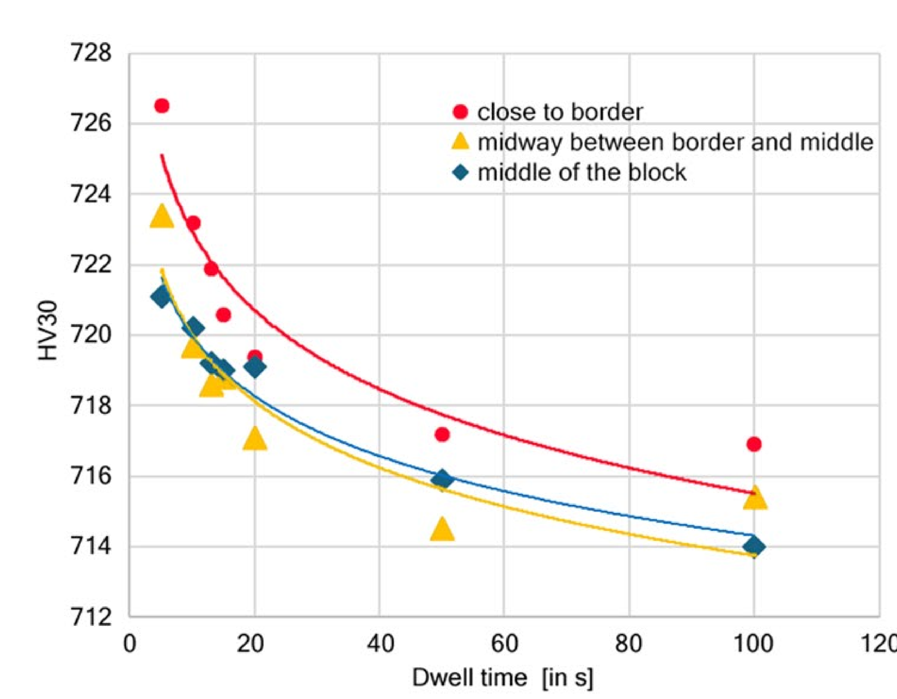

Figure 4: Influence of dwell time during indenting and the positioning of indents on the block on the measured hardness

A set of parameters to be used during measurements is established to ensure minimization of the effects of influencing factors and keeping the resulting error between different laboratories at an acceptable level.

Implementation and dissemination

Findings have been used to develop and implement improvements to the software of the indentation measurement system (IMS) currently available at TÜBİTAK UME Hardness Laboratory enabling autofocus, edge detection by image processing for circular, square and equilateral-shaped indentations and the automatic measurement of indentations. Results show a threefold improvement in speed compared to a semi-automatic system while also improving accuracy even further.

In order to enable the propagation of the hardness units to lower-level laboratories long-term stable and high-quality real reference indentations to be used as transfer standards are developed. This ensures the traceability of real indentation measurements in three dimensions rather than two dimensions calibration based on length measurements as is the current standard.

Advanced uncertainty models for BVK hardness as well as recommendations for producers of hardness measurement equipment based on the correlation between the reference systems operated by NMIs and the testing systems end users will enable consistent and comparable measurements and will advance the future development of these instruments.

The BVK indentation definitions, uncertainty models and methodology for establishment of traceability for BVK hardness measurements will be used as input to improve the relevant ISO standards, advancing hardness measurements on a global scale by consideration of the occuring imperfections and influences during hardness measurements and offering a comprehensive and easily implementabe solution.

Conclusion

The project offers a solution to the problem of inconsistent hardness measurements by defining and establishing a methodology for traceability from the NMI level to the end user by establishing universal definitions for Brinell, Vickers and Knoop indentations, their borders and a methodology for their measurement for the most widely used IMSs. Building on this, new 3D indentation transfer standards, uncertainty models for BVK hardness tests, a methodology to ensure traceable measurements from primary standards to the end user, and automation of hardness measurements will all represent significant advances in hardness metrology.

References

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Acknowledgements

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