Verifying Linear Distances for Brinell, Vickers and Knoop Hardness Testing Systems Using Image Analysis Systems

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Abstract - Image analysis has grown rapidly in industry for determining linear distances in Brinell, Vickers and Knoop hardness testing. Its ease of use and consistent results from one operator to another within a laboratory has made it a popular tool. Also the apparent quick and easy calibration techniques can give the user false security that the system is correct.

Since linear distances are a key component of the Brinell, Vickers and Knoop test, it is very important to determine if the system is correctly measuring the linear distance. Currently, the traditional method of using a stage micrometer is used to determine the optical linear part of the hardness tester [1], [2], [3], [4], [5].

Although the stage micrometer can be traceable to a national laboratory, it is flat compared to hardness indents. This does not adequately address the nature of hardness indents. Hardness indents are not flat and exhibit pile up at the edge of the indent where the linear distance is measured. In some cases where the material is very soft, the pile up can be very large. Verification using a stage micrometer is not at the same level as a hardness indent. Direct verification can best be accomplished by measuring traceable indents from a national laboratory. In addition, lighting and focus can play a significant role in calibrating an Image analysis system used for hardness. These verification methods are necessary so that Image analysis systems can maintain national and international hardness standards. This concern with the accuracy of Image Analysis has been studied in the past by NIST [6].

1. The need for the verification of hardness testers using Image Analysis.

During the last 10 years, the use Image Analysis has grown rapidly throughout the world. In general, it is user friendly and can work rapidly. Another feature is its ability to be used by several operators and still give consistent results from one user to another.

Unfortunately, while Image Analysis can be faster to operate and more than repeatable than manual systems, it is not necessarily more accurate in all situations. Image Analysis can give the user a false sense of security that the results are more correct than they are. There must be a method to determine if the results are reliable.

Whether it is a Brinell, Vickers or Knoop test, they use a measured linear distance as a component to calculate the hardness value. That linear distance is in millimeters or micrometers as shown in Table 1. This component should be traceable to SI units. The successful method of

determining traceability is different depending on whether a traditional method of filar microscope or image analysis is employed. It should be noted here that Image Analysis can be more repeatable than traditional use with scopes. However, the purpose of this paper is to illustrate how Image Analysis systems mean values can digress from a known traceable source.

TABLE 1.

Direct Parameter	SI Units	Uncertainty
Length	mm /micrometers	0.003 / 0.1

The measurements obtained by PTB and NPL were by the typical method of microscope and filar. The human eye determined the edge of the indent and the filars were moved at the proper spacing. This method can be shown in Fig 1. It should also be noted that the measurements determined at both national laboratories were not exactly the same but very close. These values were reported in millimeters. One should look at the edge of the indent in the image shown in Fig. 1. There is usually some question as to where the indent and the test surface meets. Here there must be some interpretation by the user must. This is a problem that an Image Analysis system can eliminate.

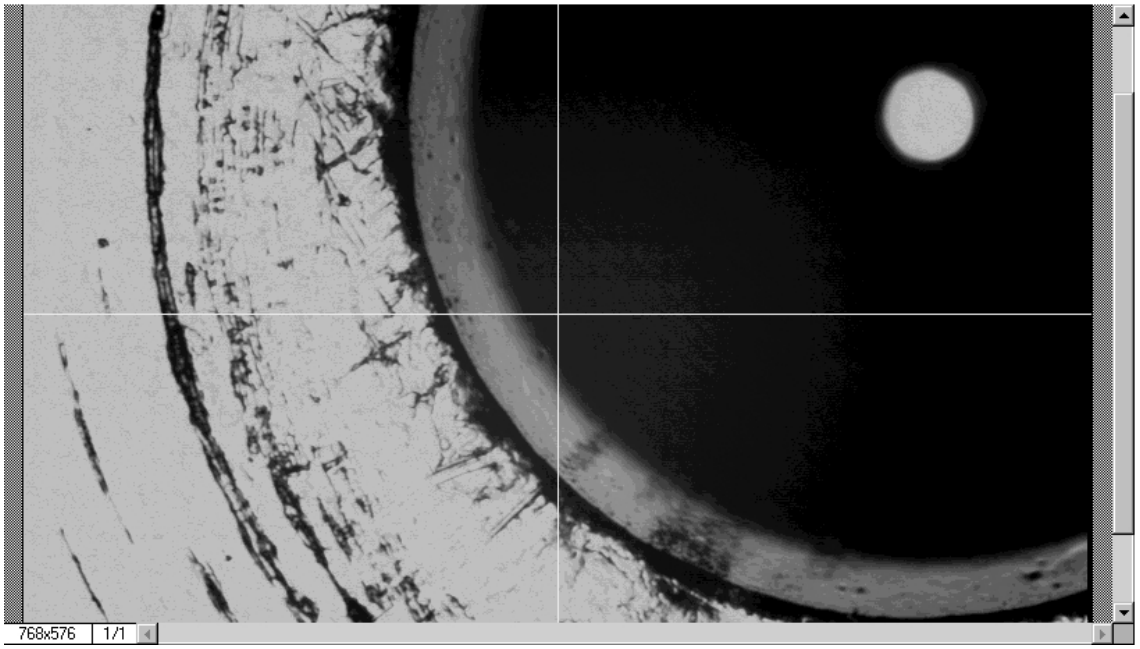

Figure 1.
Filar method used by national laboratories to measure Brinell indents.

The measurements at the secondary laboratory were done with an Image Analysis as shown by Fig. 2. The edge of the Brinell indent was determined by the computer and no human decisions were made. Before comparisons with national laboratories, the Image Analysis was verified using a flat stage micrometer from NIST. The first measurements are representative of an Image

Analysis system solely traceable from a stage micrometer. In this case the computer found the edges and displayed a diameter in millimeters.

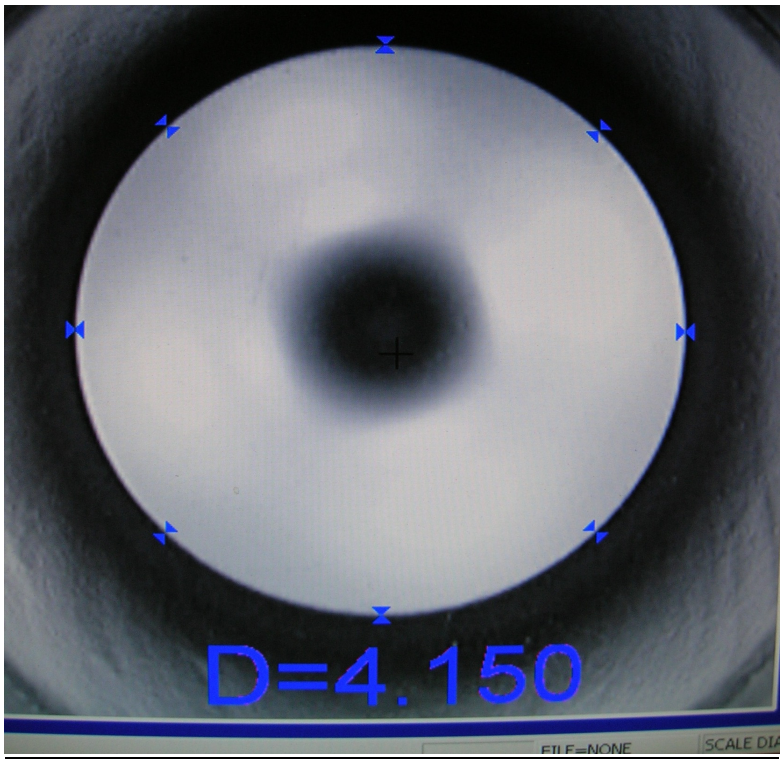

Figure 2.
Brinell Image analysis system of determining indent diameter.

2. Test Procedure

Prior to comparisons of a secondary test laboratory to two national laboratories, a Brinell test block was produced with eighteen indents of various sizes. The various sizes were created by using different ball sizes (10mm, 5mm, 2.5mm and 1mm) and different forces 187.5kgf to 3000 kgf) applied to the block. This created enough indents to compare in many situations; different size diameters and different edge pile-ups with comparable sized indents.

Prior to tests by the national laboratories, the indents were measured at the secondary laboratory using an Image Analysis system. In the beginning, the Image Analysis system was calibrated using a stage micrometer. The image system was automatic and determined the indent size without interpretation by the user. The results were recorded.

The same block was sent to two national laboratories. These indents were measured using filar as shown in Fig. 1. The results of these national laboratories served as the standard indents.

After measurements were obtained from the national laboratories, the Image Analysis system was re-calibrated using traceable measurements of the indent diameters. In addition, other comparisons were made using individual indents for adjusting the Image Analysis system.

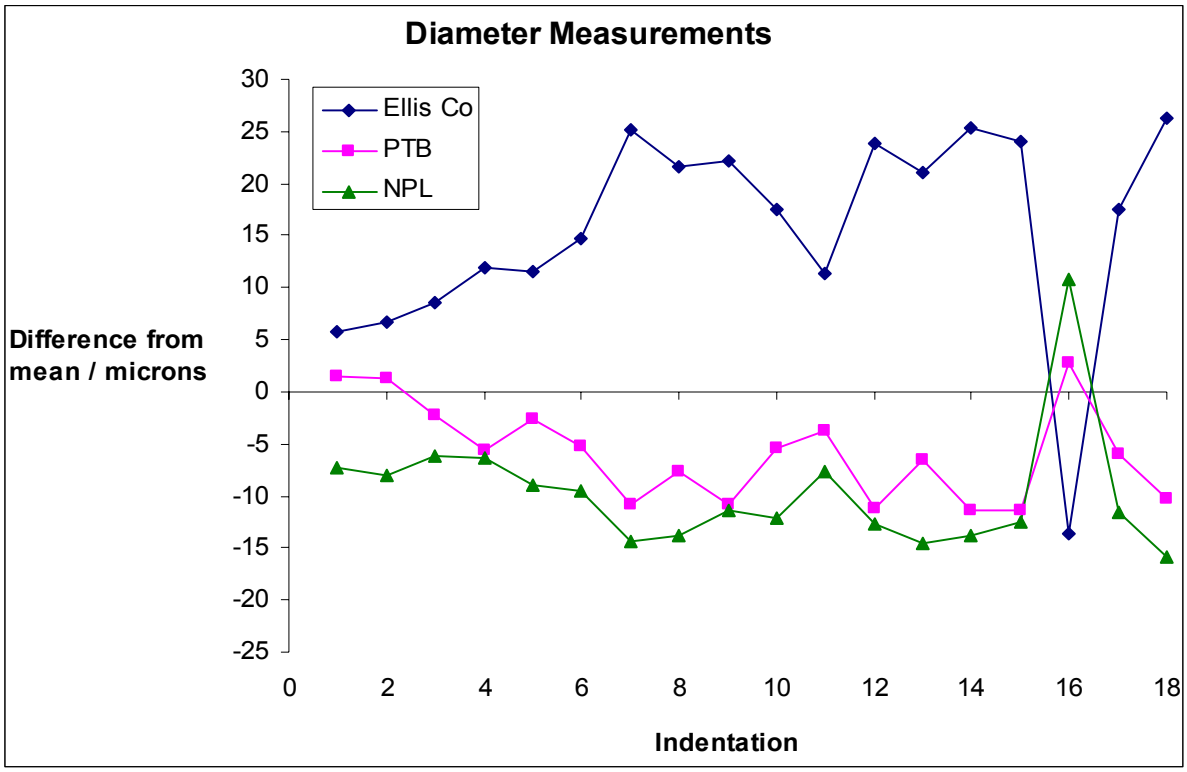

Figure 3.
Differences of Brinell Image Analysis to national laboratories at specified indents.

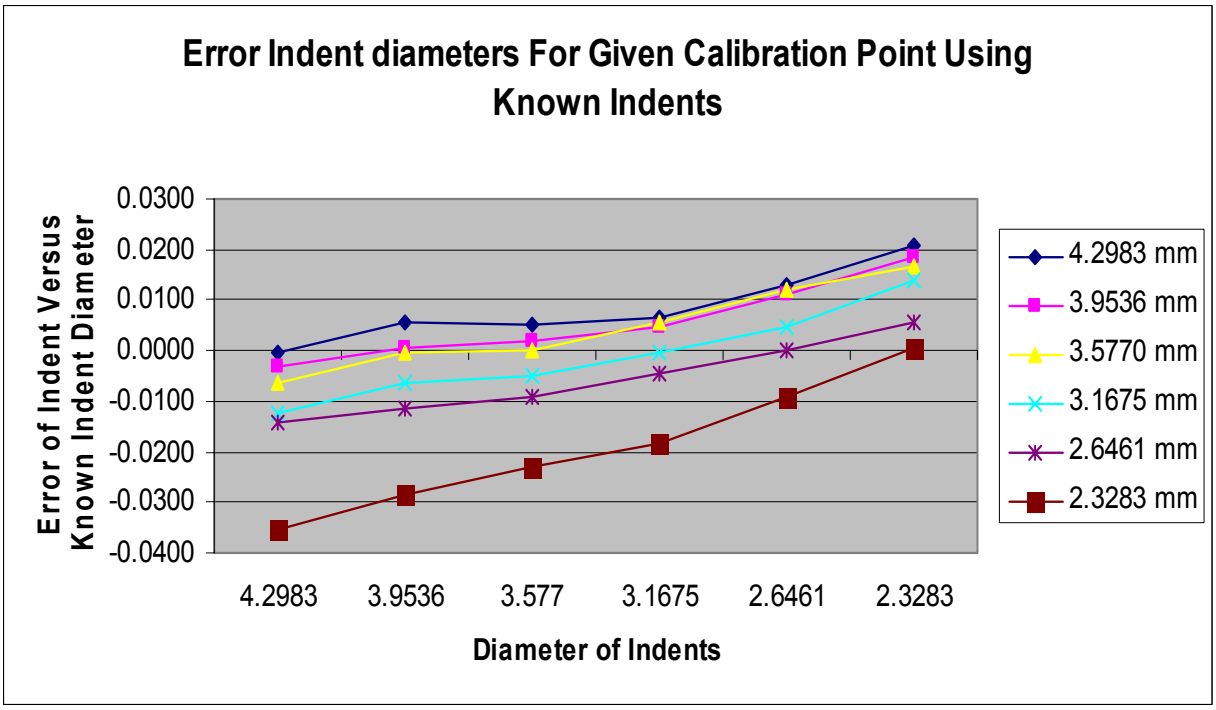

Figure 4.
Error Brinell Image Analysis when adjusted at specified indent size.

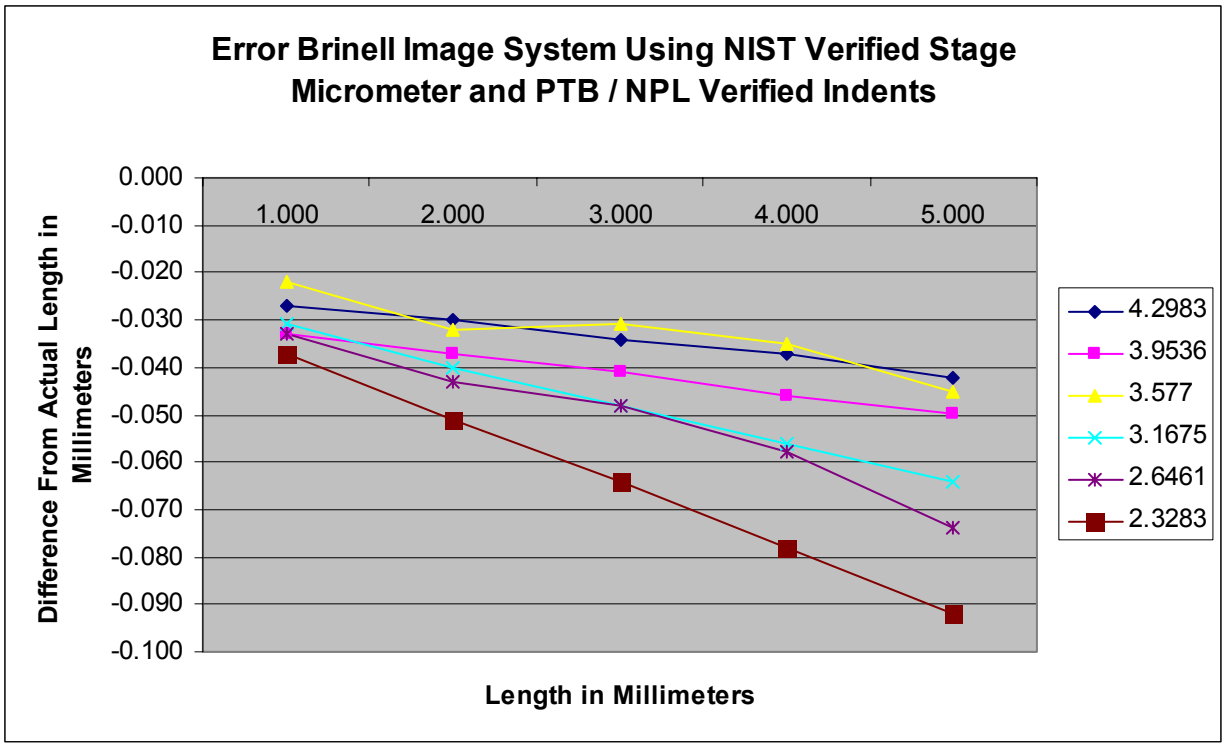

Figure 5.
Error Brinell Image Analysis reading stage micrometer at adjusted indent.

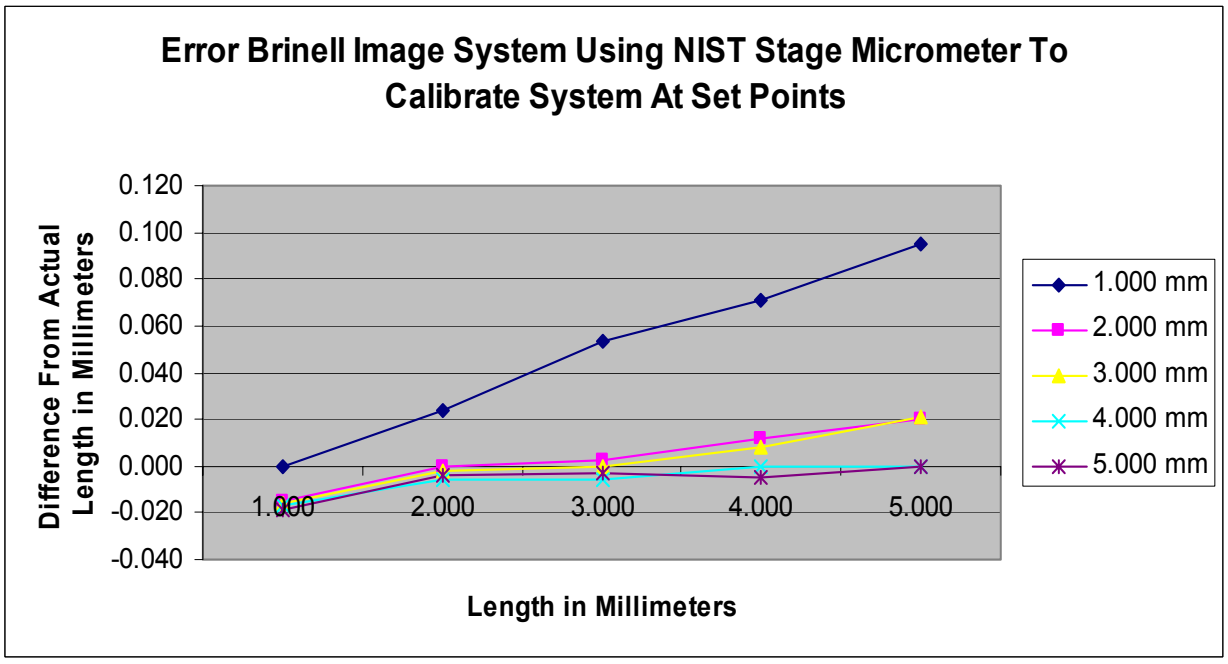

Figure 6.
Error Brinell Image analysis when adjusting at given lengths of stage micromter.

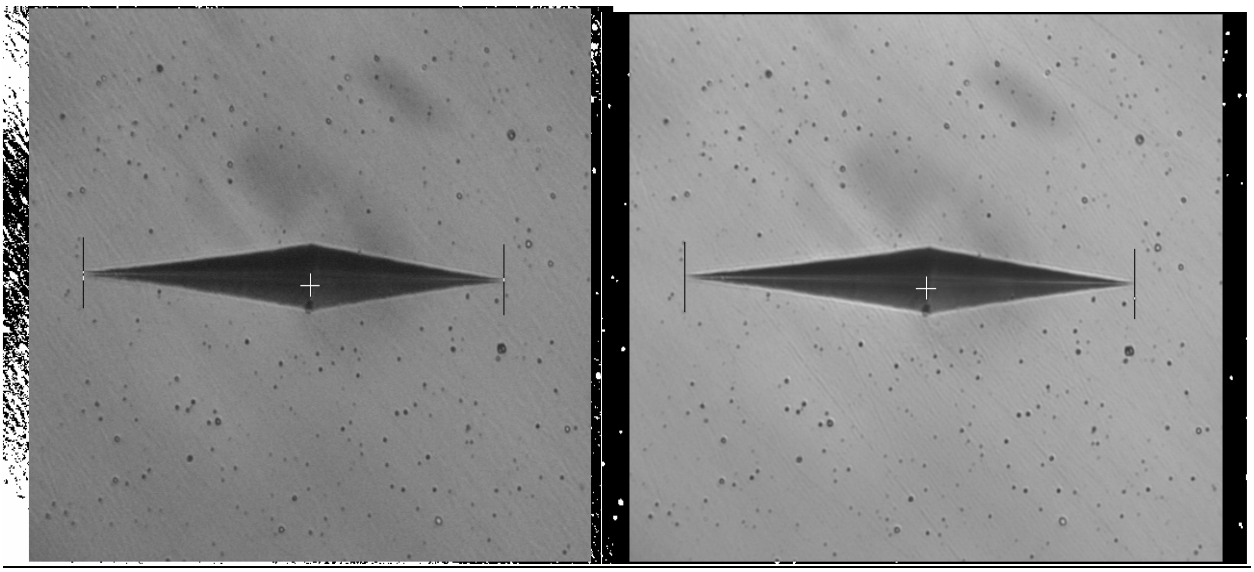

Figure 7.
Change of lighting of Knoop Microindentation Image Analysis

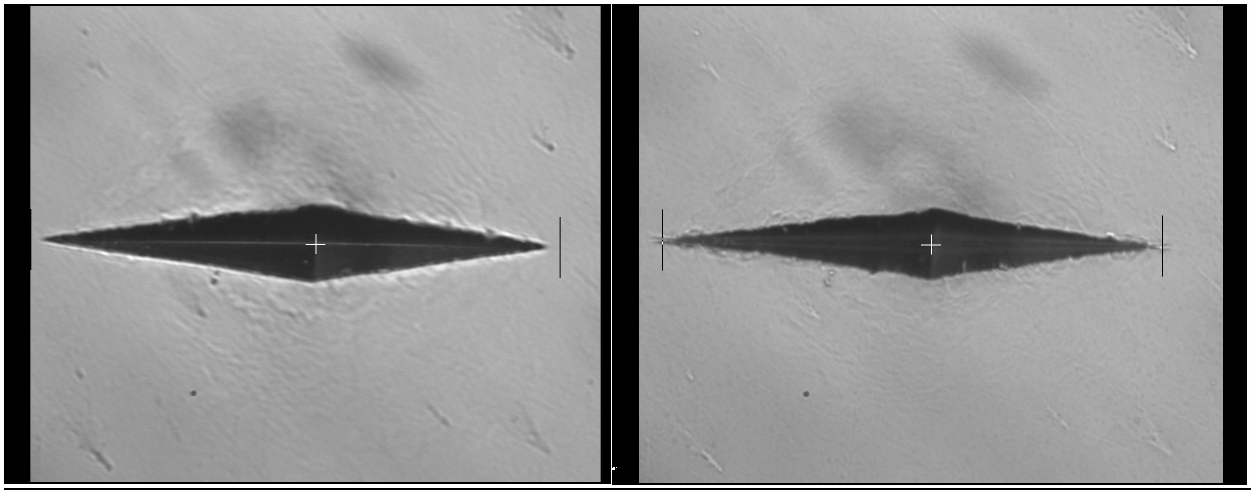

Figure 8.
Change of focus of Knoop Microindentation Image Analysis

For the Micro-indentation test, the following was done. Comparisons were made for a slight change of illumination as shown in Fig. 7 and slight change of focus as shown in Fig. 8

3. Discussion

Direct verification of the linear measurements of an Image analysis system can best be accomplished by using traceable indents from a national or secondary laboratory. This is true for both Brinell and Vickers / Knoop systems.

First let's consider the Brinell test system. When comparing results obtained from an Image Analysis system calibrated by a stage micrometer, the results will be different. Depending on the

ball size, force and diameter, the results can be much different for the Image analysis system than the traceable indents. This can be seen in Fig 3.

When adjusting / calibrating an Image Analysis system, the comparisons may not be linear. This means calibrating at any given point may not be accurate at another point. Fig 4 shows that adjusting the Image Analysis system at different traceable indents may give significant different readings at other points. If the Image Analysis system can not be adjusted all the time, an optimum size indent may be chosen. With this Image analysis system, an indent about 3.500mm is optimum.

When using only a stage micrometer to adjust an Image Analysis system, the results for reading traceable indents can vary depending on the interval chosen for point of calibration. In fact, at extreme points, the system can have very large errors. This can be shown in Fig. 5.

An Image Analysis system can have error measuring a stage micrometer when setting the Image analysis system at any point of the stage micrometer. It can be seen in Fig. 6 that the worst case scenario is adjustment at the shortest distance.

When using Image Analysis for Vickers / Knoop, the system can misinterpret an indent. It is possible to verify a micro-indentation tester with a traceable flat stage micrometer and still obtain incorrect hardness values. This is because the linear distance is a major component of the hardness value. Since the lighting and focus are easily changed in this test, it is good to have a method to verify the linear distance correctly It is possible the lighting and focus can add or cancel the errors.

When using Image analysis during micro-indentation testing, lighting and focus can play a significant role in calibrating an Image analysis system used for hardness. The slight change in illumination in Fig 7 can change the Knoop hardness for 734 HK 0.5 to 755 HK 0.5. A small difference focus will change the hardness from 189 HK 0.5 to 230 HK 0.5. This can be seen in Fig 8. To the casual observer, these changes are very small to the human eye. The Image Analysis system will detect a difference and determine a different hardness value. In some cases, these differences can be large enough to cause the tester to be out of tolerance.

While this paper illustrates the Knoop indent, the user should also be aware that errors will also occur using the Vickers test as well.

4. Conclusions

Verification methods are necessary so that Image analysis systems can maintain national and international hardness standards.

When using Image Analysis for Brinell testing, a stage micrometer is not sufficient. Verified traceable indents are best to ensure the system is giving good measurements. Also, if the user is using the Image system over a broad range of hardness values, the user should determine the optimum diameter for calibration or assign offsets. In any case, the system should always be within tolerance.

The use of an Image Analysis system is a little more complicated for a micro-indentation tester. One must understand the effects of lighting and focus. An Image System may also be verified using a stage micrometer, but in addition give more incorrect hardness values once the lighting and focus are altered. Using a traceable indent, the tester can be adjusted or verified.
For both the Brinell and Microindentation hardness tests, the user should consider obtaining standardized indents from a primary or secondary laboratory for the purpose of verifying the tester's readout system.

Acknowledgment

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