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VERIFICATION OF IMAGE ANALYSIS SYSTEMS FOR MEASURING BRINELL INDENTATIONS

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Abstract: Recently image analysis systems have become available and are now used widely in industry. While there are great benefits in using this method to measure Brinell hardness indentations, a method to verify these systems is needed. Older methods using flat stage micrometers exclusively are not sufficient. Methods and guidelines for the use of these systems should be developed.

Keywords: Brinell, indentation, image analysis.

1. IMAGE ANALYSIS COMPARED TO PREVIOUS METHODS OF DETERMINING BRINELL INDENTATIONS

All Brinell testing requires an indentation be made into the material which is tested. This Brinell indentation is made by using a known size ball (of diameter 1 mm, 2.5 mm, 5 mm, or 10 mm, and made of tungsten carbide, in most cases) and applying a known force as specified in ASTM E-10 [1] and ISO 6506-1 [2].

The Brinell hardness value is calculated using the ball size used, the force applied during the test, and the size of the measured indentation. It is relatively easy to control and measure the ball size and the force applied, however the measured indentation can be difficult to determine. The inability to measure the indentation size correctly can affect the final Brinell hardness value significantly.

There are significant differences between the older methods of determining the Brinell indentation using microscopes and the newer methods using image analysis.

Older methods for determining Brinell indentations use a microscope either fixed or variable focusing. In either case, fixed focus or not, the user must determine by eye where the edge of the Brinell indentation is. This human interaction can yield different results of indentation diameters from one individual to another. If one introduces focus of the microscope, the user can also obtain different indentation diameters depending on how the focus is adjusted.

Image analysis allows the computer with a camera to determine the Brinell indentation size automatically. In a semi-automatic mode it can be finely adjusted by the user. This method of adjustment is done by the user to calibrate the image system. However, in a fully automatic mode, the user leaves all discretion of attaining an indentation size to the computer. In some cases, it is possible that the value obtained is different than that obtained through a microscope.

Microscopes and handscopes have fixed or moving lines to measure the Brinell indentations. In either case the user must adjust the lines to the perceived edge of the indentation.

Image analysis systems are calibrated against known distances as opposed to older microscope verification methods. In general, an image system counts the pixels it sees in an image. It is the computer that converts the pixels counted to a distance. Usually a flat stage micrometer with traceable measurements is used to calibrate the image system. A known distance on the stage micrometer is compared to the image system readout. The system parameters are then set against these traceable values.

Image systems usually have a readout system with a higher resolution than a typical Brinell microscope. Typical Brinell microscopes have a 10 µm to 50 µm resolution compared to a 1 µm to 10 µm resolution of the image analysis system.

In general, image systems can give more repeatable results than the typical Brinell microscope using the same operator or from one operator to operator. This does not mean the results are more accurate. Further discussion will show why this is not necessarily true in all cases.

2. CHARACTERISTICS OF BRINELL SYSTEMS USING IMAGE ANALYSIS

Since image analysis systems operate differently to traditional microscope systems, there are areas of concern. Most users are not aware of these characteristics and use them without realising the possible errors associated with the system. This has been studied by NIST [3].

2.1. Determining the edge of the indentation

The edge of the Brinell indentation must be determined in order to measure the diameter. Fig. 1 shows a typical Brinell indentation. Image systems do not use lines as in the traditional method with microscopes. The computer captures the image and determines the edges. A computer measured indentation can be seen in Fig. 2. Usually the computer uses shades of light and dark. If the line definition is not well defined, the computer may assume the incorrect edge. Where the human eye may overlook imperfections on the surface or poor line definition, the computer cannot. In some cases, the image of the computer image analysis indentation can appear perfectly round or correct, but still give an incorrect diameter value.

In this study, a Brinell test block was indented with 18 different sized indentations. This was done by varying the ball diameters and the forces. Table 1 shows the description of the indents and diameters. Initially, the indentations were measured at a secondary laboratory using an image analysis system. Afterwards, the Brinell block was sent to two national laboratories (NPL and PTB) to measure the same indentations.

It is therefore possible for the computer to determine a different diameter than the human eye can. In some cases the lighting can change the way the computer see the edge of the indentation.

2.2. Fixed focusing of image systems

Most Brinell image analysis systems are fixed focus. This can present itself as a problem because Brinell indentations are not flat. Usually material piles up at the edge. For this reason, the edge is at different heights for all indentations at various hardness ranges, ball sizes, and forces used. When compared to a measured indentation using a microscope with focus, the determined diameter can be different.

In Fig. 3, diameter values were compared for an image analysis system against the two national laboratories. In this case, the image analysis system was verified against a stage micrometer measured by a third national laboratory (NIST).

In Fig. 4, the differences in hardness values are shown as a result of the differences of indentation diameters.

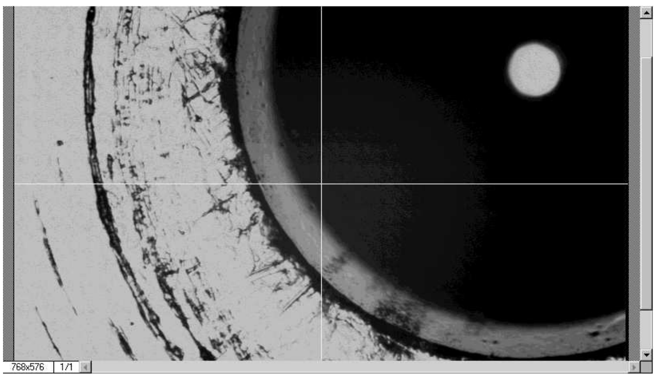

Fig. 1 Brinell indentation shown by NPL microscope

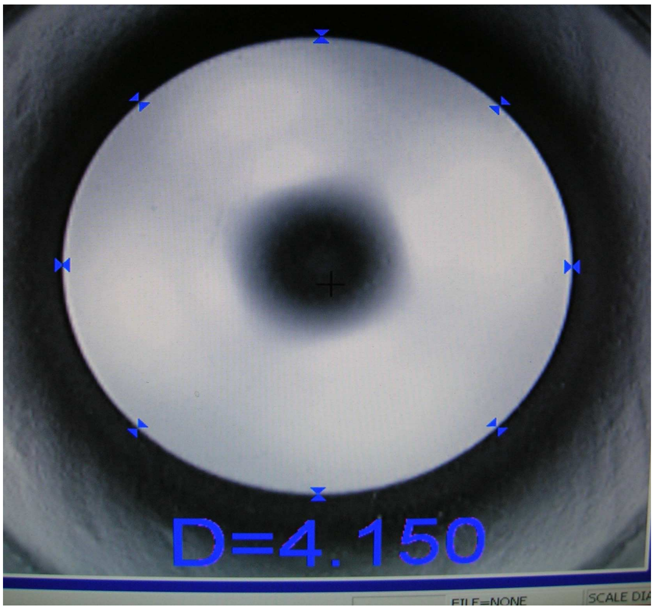

Fig. 2 Brinell indentation measured by image analysis

TABLE 1 Indent description and diameters

Indent	Ball / KGF	Indent Size mm
1	10/3000	4.2983
2	10/2500	3.9536
3	10/2000	3.5770
4	10/1500	3.1675
5	10/1000	2.6461
6	10/750	2.3283
7	5/2000	3.3616
8	5/1500	2.9447
9	5/1000	2.4588
10	5/750	2.1718
11	5/500	1.8108
12	5/250	1.3316
13	2.5/250	1.2431
14	2.5/187.5	1.8092
15	2.5/62.5	0.6673
16	1/187.5	0.7647
17	1/62.5	0.6098
18	1/31.25	0.4482

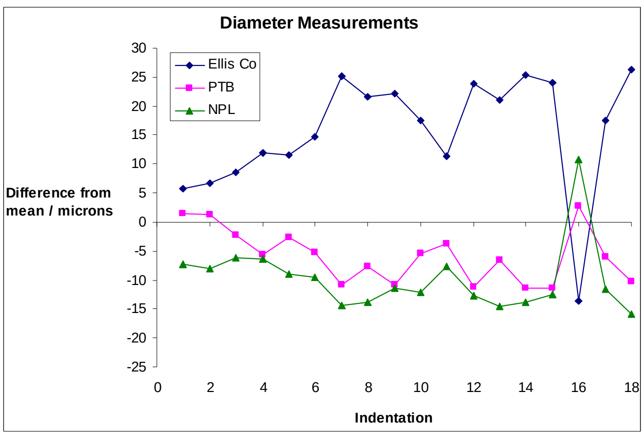

Fig. 3 Non-linearity of image analysis against microscopes

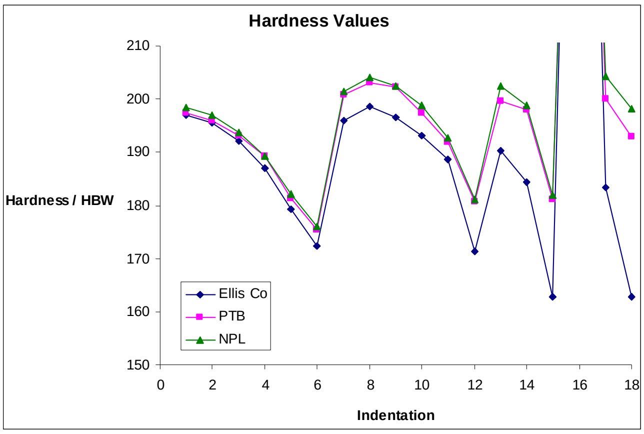

Fig. 4 Non-linearity of image analysis against microscopes

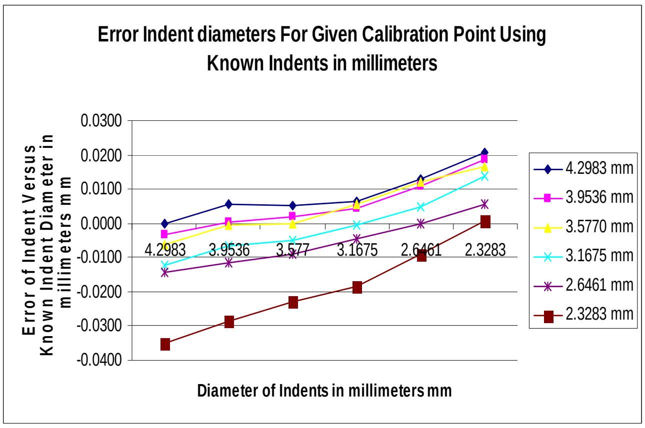

Fig. 5 Image analysis diameter measurements (10 mm ball) after adjustments to known indentation sizes from national laboratories

2.3. Non-linearity of image systems versus microscopes

While it is possible to set up an image analysis system against a traceable standard, the system may not be accurate over the full range of diameter sizes. Also, the same size indentations for two different size balls can yield different measurements.

The image analysis system was calibrated to a block with standardised reference indentations traceable to the two national institutes. The traceable indentations were measured at the national institutes using calibrated microscope systems. However, when the image analysis system is set up to agree at one end of the indentation range using these series of traceable indentations, it does not agree across the whole range of indentation sizes. This can be seen in Fig. 5. This is an area of concern since most image analysis systems are used over a range of indentation sizes.

When using a 10 mm ball (indentations 1 to 6), it can be seen that this image analysis appears to agree better over the 2 mm to 4 mm range when adjusting the system to agree at about 3.5 mm. Adjusting to other points results in worse agreement. These lines are closest to the 0.000 mm line in Fig. 5.

If the image analysis system is adjusted at various points on a stage micrometer, it will read the indentations differently at different points. The image analysis system never agreed exactly to the lengths on the stage micrometer. They were always short, but the best correlation occurred when the image analysis system was adjusted at 5 mm. Using shorter distances made the situation worse, as can be seen in Fig. 6.

Adjusting the image analysis to various points on the stage micrometer yielded different measurements on the stage micrometer. The lengths measured on the stage micrometer were best when the system was adjusted at the greatest length, as can be seen in Fig. 7.

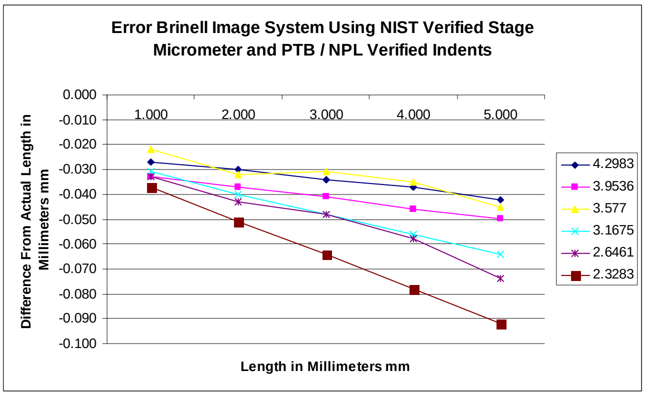

Fig. 6 Image analysis diameter measurements after adjustment to a stage micrometer from a national laboratory

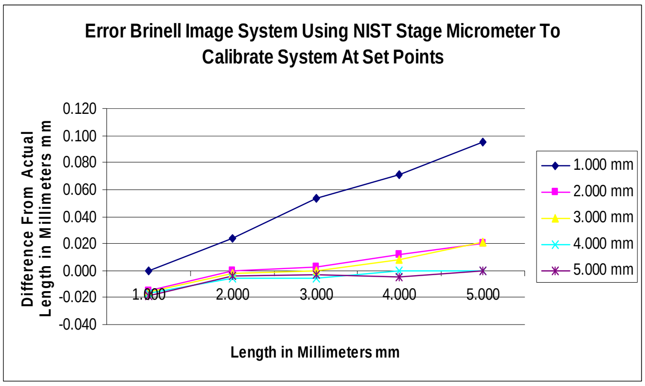

Fig. 7 Image analysis length measurements after adjustment to various points on a stage micrometer from a national laboratory

2.4. Ball size influence

The ball size greatly influences the accuracy of the image analysis system. As seen in Fig. 3, as the ball size decreases, the accuracy decreases as well. What has occurred here is that the image analysis system has been calibrated at one ball diameter / force and at one end of the range of indentation sizes. While it may agree at one indentation size, it cannot at another.

While the measured diameter values digress from one end of the range to the other in all cases, the situation appears worse as the ball size decreases.

2.5. Pile up around the indentation edge

Two indentations of about the same diameter may not agree with an image analysis system. There is a significant difference when the ball size is reduced. There is less agreement in image systems versus a microscope. Of course, the heights of the indentations are different. The lack of focus may contribute to the errors.

3. CONCLUSION

Image analysis systems are now broadly used throughout the world. It is important that these systems correctly perform an analysis of the Brinell indentation. These errors of measuring the indentations can cause large differences in the Brinell hardness values.

A measured indentation is necessary to calibrate an image analysis system. The use of such a reference indentation is a better method than using a flat stage micrometer because it replicates the three dimensional geometry which the systems will be required to measure.

The method for calibration of a image system should be simple and traceable to a national standard.

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