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AUTOMATIC MEASUREMENT OF BRINELL AND VICKERS HARDNESS USING COMPUTER VISION TECHNIQUES

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Abstract – In this paper we present a methodology to automatic measure the hardness indentation, by using Computer Vision techniques. The main focus is the indentation measurement. With this methodology the user's skill has no influence in the final hardness result.

Keywords: automatic measurement of hardness indentation, computer vision.

1. INTRODUCTION

The hardness test is widely employed in materials research and quality control, because it is a less onerous and faster method to obtain some material mechanical properties. However, the results of the hardness measurements are subjected to the uncertainty of various parameters of the test method like test load applied, indenter, time of load application, device for indentation measurement and the operator's skill. Therefore, it is important to minimize the uncertainty relating to each parameter in the test method that can influence the final measurement, in order to assure the reliability of the resulting hardness value.

Nowadays, the industry uses several methods for determination of the hardness indentation mark, and the selection of the indentation measurement method varies according to the size, the automation level of the industry and also the purpose of the test. The image analysis technique is a very useful tool in the measurement of hardness indentation, since its application allows the measurement of indentation characteristics that would be impossible with the employment of conventional techniques (Pires et al., 2001).

2. METHODOLOGY

The methodology developed permits an automatic measurement of the hardness indentation. Adopting this methodology, the user's skill has no influence in the final hardness result. Commercial image analysis systems used in hardness tests needs some previous image processing knowledge of the operator. In our system the software developed choose the best methodology, according to the hardness test and range.

We present the results obtained by different image techniques applied to hardness analysis. Physically, a hardness image consists in a gray tone pixel matrix. The first step of the system consists in threshold the image, without loss of indentation boundary information. After the segmentation process we have the indentation as a dark area, in contrast to the white background. This simple process can be a critical one, if we use inadequate pre-processing filters. If the user doesn't have image processing knowledge, they can cause serious mistakes in this process stage. Commercial systems, generally, present uncertainty hardness forms. A meticulous observation will show that the boundary of the indentation is irregular. Those irregularities turn, particularly for human beings, the indentation measurement more difficult and imprecise.

Some techniques of Computer Vision may be used to minimize the lack of clearness of the indentation borders (Leta et al, 2001). The implementation of those techniques allows the analysis of the contour of the dark image, and can be divided in three steps: (1) pre-processing and segmentation of the image; (2) recognition of the indentation; and, (3) measurement of indentation dimensions.

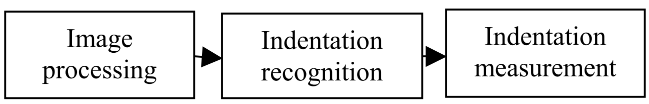

Fig. 1. Overview of the system.

The choice of the most appropriate method to pre-processing and threshold the image, in its two main components (the indentation and the background), must be sufficient robust in order to generate images without quality loss. The following pre-processing techniques were used (Pitas, 1993):

Brinell
- Low-pass filter - 3x3 (Fig. 2a)

- Global Threshold - 25% (Fig. 2b)
- Median filter - ray 9 (Fig. 2c)
- Morphological operation - closing (Fig. 2d)

Vickers
- Modal Threshold
- Morphological operation - closing

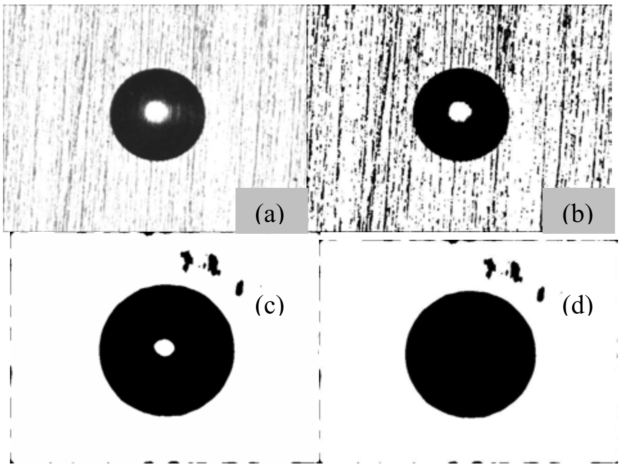

Fig. 2. Pre-processing procedures applied to (a) original image: (b) low-pass filter 3x3; (b) global threshold in 25%; (c) median filter; (d) morphological operation.

The recognition process guarantees that the only object analyzed is the indentation one, i.e. no image noise will be taken into account. In Fig. 2 (d) it is possible to observe that there are some objects in the image, that are noise. In order to remove those features we applied 4-neighborhood algorithm (Heijden, 1994).

We selected the following samples to test the proposed methodology: Brinell and Vickers standard hardness blocks. Those blocks have traceability to national and international standard specifications. In Figure 3 we can observe two original images of Brinell indentation (a and c), and the result of the image processing and indentation recognition (b and d). In Figure 4 we can observe two original images of Vickers indentation (a and c), and the result of the image processing and indentation recognition (b and d).

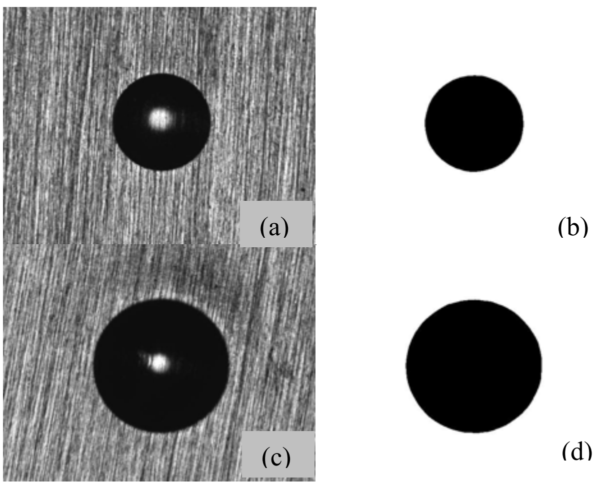

Fig. 3. Brinell hardness: Original image 1 (a); Processed image 1 (b); Original image 2 (c); Processed image 2 (d).

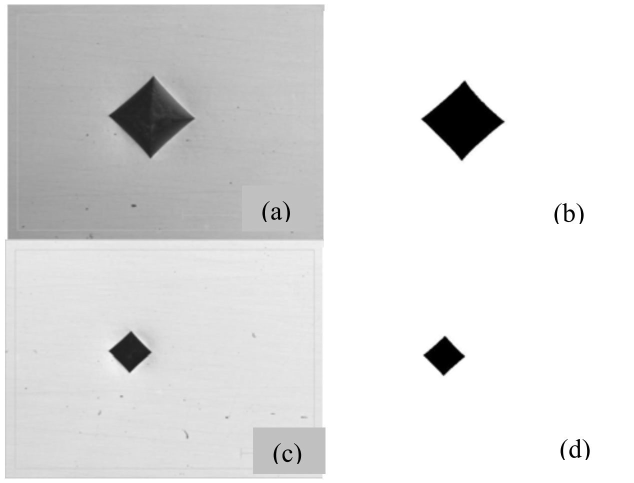

Fig. 4. Vickers hardness: Original image 3 (a); Processed image 1 (b); Original image 4 (c); Processed image 2 (d).

The indentation measurement consists in the diameter automatic measurement in Brinell hardness and diagonal automatic measurement in Vickers hardness. We developed four methodologies to each hardness test. We used the following methods to obtain Brinell hardness: (1) coordinates difference (CD); (2) area (A); (3) perimeter (P); and, (4) three equidistant points (TEP). In the case of Vickers hardness we used the same methods, except the fourth. The fourth method used consists in the vertex detection of the indentation (VD).

The coordinates difference (CD) consists in obtaining the indentation diagonal (Vickers) or diameter (Brinell), based on the maximum and minimum coordinates of the indentation pixels (picture elements, i.e. smallest image element) (Fig. 5 and Fig. 6). In the area method we get the diameter or diagonal from the indentation area, by the sum of all indentation pixels. In the third method we detect indentation perimeter using the 4-connected pixels methodology and extract the characteristic using appropriated formulae (Heijden, 1994).

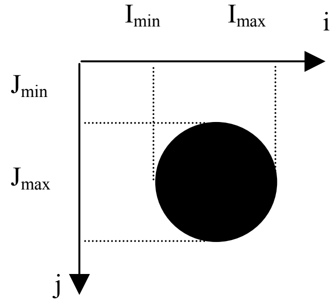

Fig. 5. DC applied in Brinell.

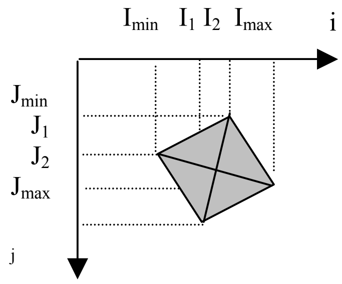

Fig. 6. DC applied in Vickers.

In the three equidistant points method, used in Brinell hardness, we evaluate the diameter from 3 equidistant points that belong to the outline of the black area (Fig. 7). The algorithm stores all outline coordinate pixels. In order to reduce the error, specially the noise error in the perimeter, the diameter is obtained by the mean of all subsets of 3 equidistant points of the indentation perimeter, considering a deviation standard of 20 %.

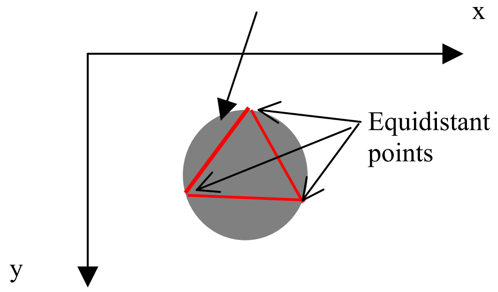

Fig. 7. Three equidistant points.

The vertex detection of the indentation, used in Vickers hardness, consists in obtaining the diagonal from the indentation vertexes recognition. The VT algorithm includes the following steps: (1) boundary pixels storage using TEP approach; (2) a random insert parallelogram to the indentation is generated; (3) the distance of each pixel to the nearest parallelogram side is computed; (4) a possible vertex is indicated by the greatest distance; (5) a real indentation vertex is assured by proceeding turning the parallelogram and repeating the calculation, until finding the four points that best characterize the diagonal (Fig. 8 and 9).

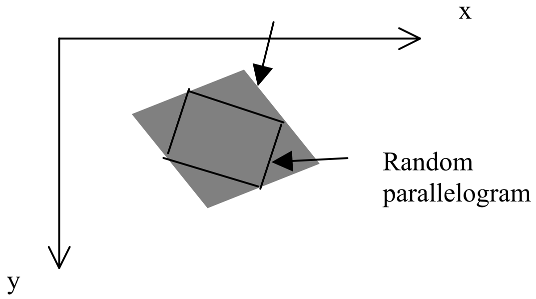

Fig. 8. Inserted parallelogram.

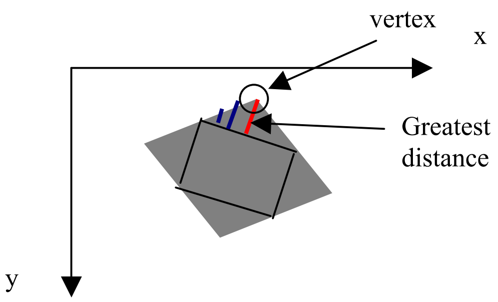

Fig. 9. Distances between the parallelogram and the indentation perimeter. The red one is the greatest distance.

3. RESULTS

The algorithms introduced in the previous item were implemented and applied in the images obtained by hardness tests in standard hardness blocks.

In the following tables we present a comparison of the obtained errors by using the developed vision techniques. In those results we consider the same image pre-processing and indentation recognition procedures, which consist in applying a global thresholding and a set of morphologic filters. We highlight the tests' characteristics above, which refers to the images presented in Fig. 2 and 3:

Brinell Hardness (Fig. 2)

- Hardness Standard: 679,6HB (Fig. 2 (a)) and 936,3HB (Fig. 2 (c))
- Applied force: 187,5 kgf
- Sphere Diameter: 2,5 mm
- Amplification: 50x

Vickers Hardness (Fig. 3)

- Hardness Standard: 833 HV10 to both images (Figure 3 (a) and (c))
- Applied force: 10 kgf
- Amplification of 200x (Fig. 3 (a)) and 100x (Fig. 3 (c))

In the tables bellow, true value (TV) consists in the certified value of the standard. The obtained errors are related to the certified values.

TABLE 1. Diameter of Brinell Hardness test and errors – Image 1

	Image 1	
	Diameter (μm)	**Error (%)**
CD	688,1	1,25
A	686,7	1,04
P	747,7	10,02
TEP	683,9	0,63
TV	679,6	-

TABLE 2. Diameter of Brinell Hardness test and errors – Image 2

	Image 2	
	Diameter (μm)	**Error (%)**
CD	933,9	-0,26
A	936,7	0,04
P	843,8	-9,88
TEP	933,7	-0,28
TV	936,3	-

TABLE 3. Diagonal of Vickers Hardness test and errors – Image 3

	Image 3	
	Diagonal (μm)	**Error (%)**
CD	143,53	3,8
A	140,14	6,07
P	113,97	23,61
VD	143,57	3,77
TV	149,2	-

TABLE 4. Diagonal of Vickers Hardness test and errors – Image 4

	Image 4	
	Diagonal (μm)	**Error (%)**
DC	141,9	4,89
A	142,81	4,28
P	106,37	28,71
VD	142,01	4,82
TV	149,2	-

The choice of the best method depends on the hardness range. Observing tables 1 and 2, it can stand out that the area method used to obtain the diameter presented the best result for the smallest hardness. Therefore, the results obtained by the three points equidistant method shows that it is more robust, for both, image 1 and 2. It points out that to an automatic method the best choice is to use TPE procedure.

In Vickers hardness, the methods DC and VP are more stable, and increasing the image amplification we can note that the error decreases.

For both, Brinell and Vickers hardness, the perimeter approach presents the largest inaccuracy, this fact occurs because any irregularity in the border contributes to increase or decrease the perimeter value. Although the pre-processing techniques are useful to obtain best images, in the other hand, they can generate those irregularities.

4. CONCLUSIONS

The obtained results show that according to the hardness test and range, some methodologies presents better results then others. In this paper we comment these results and we point out the best one for each case.

The largest difficulty in creating an automatic method, without interference of the operator, refers to the different qualities of test images, as it can be observed in Fig 3 (a and c) and 4 (a and c). Independent of the image nature, a system in this context should be capable to produce results with smaller errors then those obtained in conventional methods. The developed methodology presents better results in the analysis of small hardness materials.

This article organizes the main stages of a system for hardness automatic measurement, which includes the pre-processing stage, the indentation recognition and indentation analysis itself.

We also present a brief Computer Vision review applied to hardness indentation measurement.

It stands out that the choice of the pre-processing techniques adopted, consists of a fundamental point for good results. The inadequate choice can take to increments or reduction of the pixels' number in the impression and, consequently, to the incorrect extraction of the diameter or diagonal.

Therefore, in spite of some of the results, sometimes they possess not smaller errors than the conventional methods, it should be stood out that the absence of human being interference in obtaining of the diameter or diagonal is specially important. In this context, to acquire better results it is interesting to develop other image processing and analysis techniques applied to hardness experiments.

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