CLEMEX

Image Analysis Report

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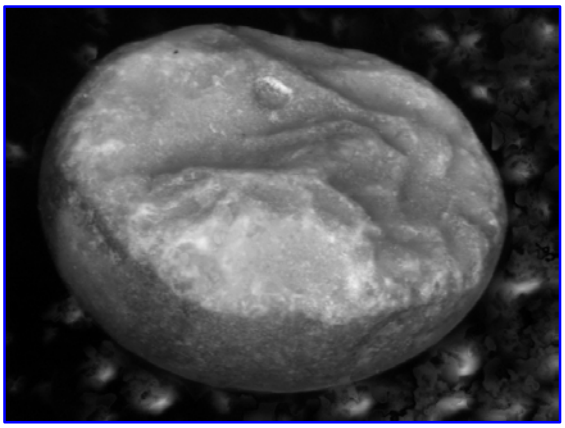

Ball Wear Analysis

Sample Description

Four small vials were received, containing balls used in the refining industry for fragmenting petroleum molecules. The vials are numbered from #1 to #4. Vial #1 contains new balls, #2 contains slightly worn balls, #3 contains worn balls, and vial #4 contains fragmented balls.

Purpose of Analysis

To show that the Clemex Vision image analysis system can classify a group of balls by degree of wear. The classifications mentioned in the sample description are the ones to be used.

Equipment Used

Image Analyzer:	Clemex Vision, version 2.0 (Impak, 640 or 1024).
Microscope:	Nikon Optiphot-150 (Obj.: 5X).
Lighting :	Reflected light, on black background.
Stage:	Motorized Marzhauser ek8b-s1 (75 x 50 mm) with autofocus.
Stage Controller:	Clemex ST 100.
Camera:	Sony XC-77CE (black and white).

Procedures

The analysis was made on a black background, using reflected light, with the balls placed on a sticky surface to ensure that they would remain motionless. A 50X magnification was used with a calibration factor of 3.3 µm/pixel.

A ball from vial #3 (worn balls) is shown on the cover page. By using the *Multi Layer Grab* instruction, we obtain an image[1] of the ball, reconstructed from 17 different images and thus appearing to be in focus over the whole surface. Examples of reconstructed images for each degree of wear are presented in Appendix B.

[1] Intermediate images and the final reconstructed image are presented in Appendix A.

Using the *Gray Threshold* instruction, the gray levels corresponding to the ball are placed into the red bitplane (binary plane), as shown in Figure 1. The reflectivity of the ball is extracted from the gray levels underneath the red bitplane, and provides the first measure of the degree of wear. The surface of the red bitplane also provides a measure of wear in the case of fragmented balls.

The gray level *Kirsh* operation causes the raised or rough sections of the ball to appear white on a black background (Figure 2). These two features will be considered to represent the "texture" of the ball.

Using the *Gray Threshold* instruction, the green bitplane is associated to the lightest gray levels (Figure 3). The ratio the of green to red bitplanes will allow for the classification of the ball's texture and forms a third wear index.

Using these indices, the objects are classified in one of the four categories. Each category is identified through the use of a different bitplane. Measuring the percentage of the balls classified in any of the four categories provides a definite rating as to which group the balls belong to.

Finally, in Figure 4, a Results page from the Clemex Vision Software is shown. A graph of the percentage of balls in each category generated during the analysis of sample #3 is shown.

The most significant image[2] modifications and final results are as follows:

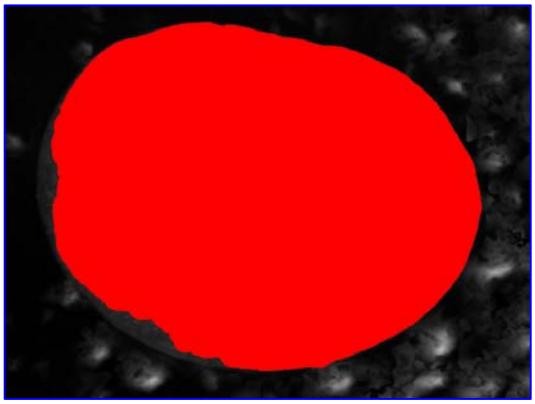

Figure 1: Red *Thresholding* of the ball on the cover. This ball comes from sample #3 (worn balls). 50X.

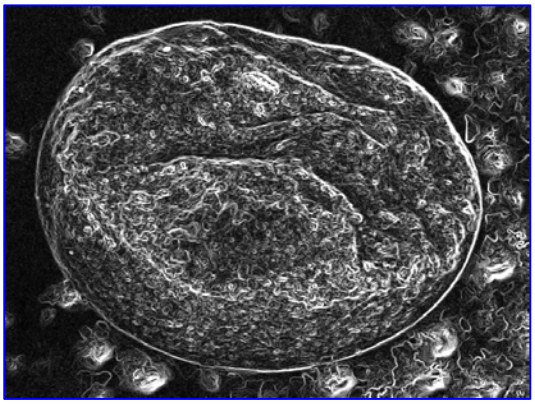

Figure 2: *Kirsh* Transformation of the original image (cover page), to make the ball's texture visible. 50X.

[2] Note that some image details may not be clear due to printing resolution.

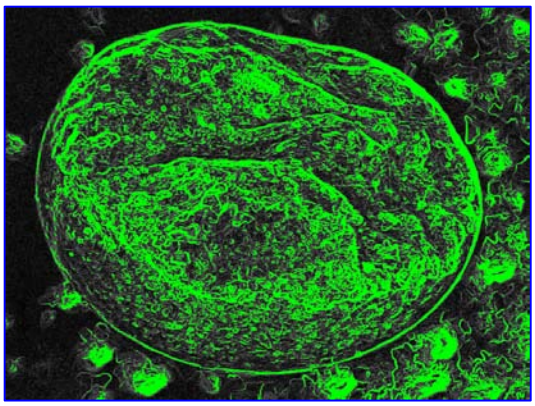

Figure 3: Green *Thresholding* of the textured areas which correspond to wear. 50X.

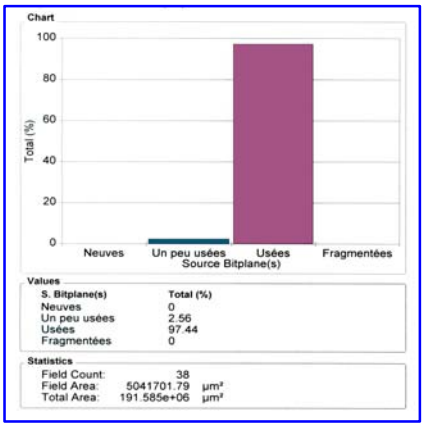

Figure 4: Results page from Clemex Vision, showing the percentage of balls in each category for sample #3. *Neuves: New; Un peu usées: slightly worn; Usées: worn; Fragmentées: Fragmented.)*

Discussion and Conclusions

The balls were randomly placed, onto a sticky surface (in order to prevent them from moving around). If a large number of samples were to be analyzed, the use of a grid to hold the samples in place should be considered. The motorized stage's displacement would thus always be the same.

Given the size of the balls (± 2mm), a low-power objective must be used to keep them entirely within the visible area (as much as possible). Nevertheless, the magnification must be sufficiently high to resolve the texture of the ball's surface. A magnification of 50X was found to be the best compromise for this analysis.

Considering the shape of the balls and the magnification used, it is only possible to focus on small sections of an object at the same time. The *Multi Layer Grab* instruction is thus vital to reconstruct the complete image from the several images taken at different Z positions, each containing only a small focused area. The Z displacement of the motorized stage was doubled in order to increase the speed of the *Multi Layer Grab* instruction. Again, an example of intermediate images and final reconstructed image is presented in Appendix A.

It was found that reflected light and a black background are the conditions which allow for the best resolution of surface details, and thus to obtain the greatest variation in gray levels from one category to another.

Using the analyzer, a number of different factors were measured on balls belonging to each of the four categories. The results obtained were compared

using graphs, and those which showed a clear-cut variation between categories were retained for use. These indices are: the size, the gray intensity and the texture. Although none of these three factors alone is enough to categorize the balls according to the four wear levels, their combined use makes classification possible.

For a group of balls, the Clemex Vision image analysis system can automatically calculate the percentage of each of the four categories to which the balls belong. From there, the final categorization is easily done.

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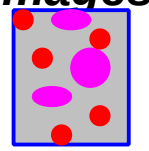
Image Analysis Report

Appendix A
Images



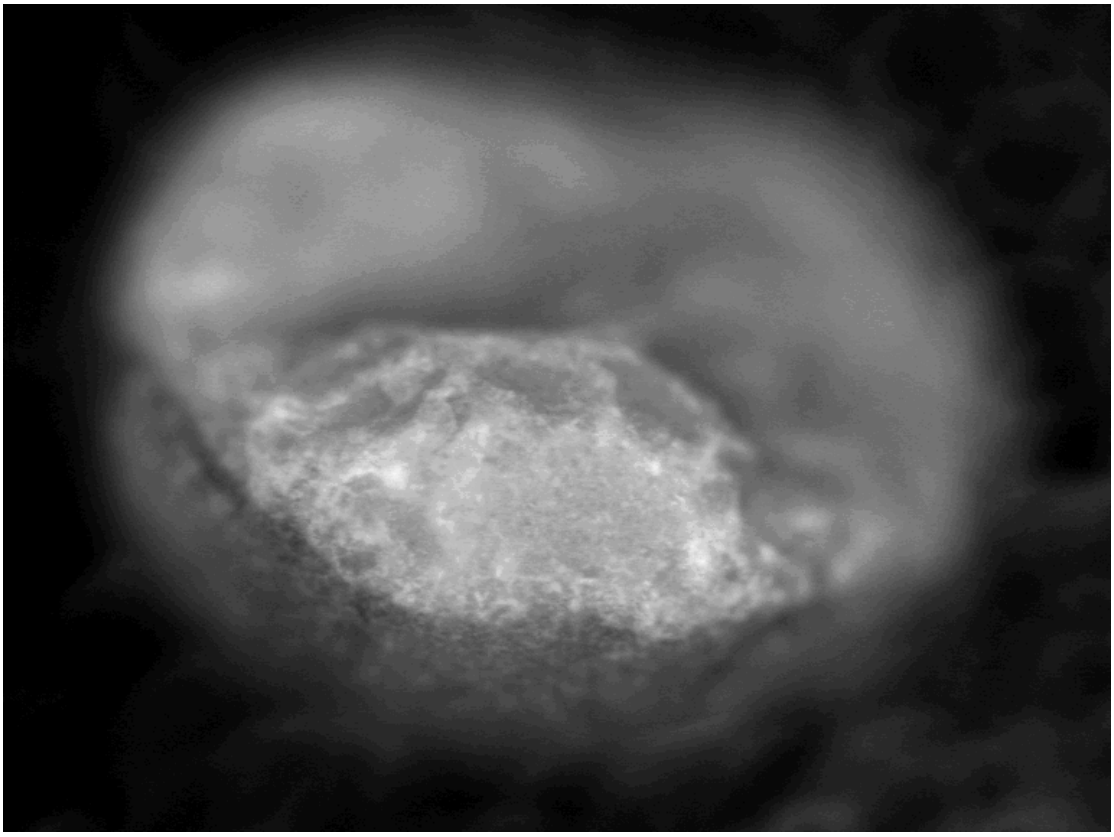


Image 1: Ball with focus on top.

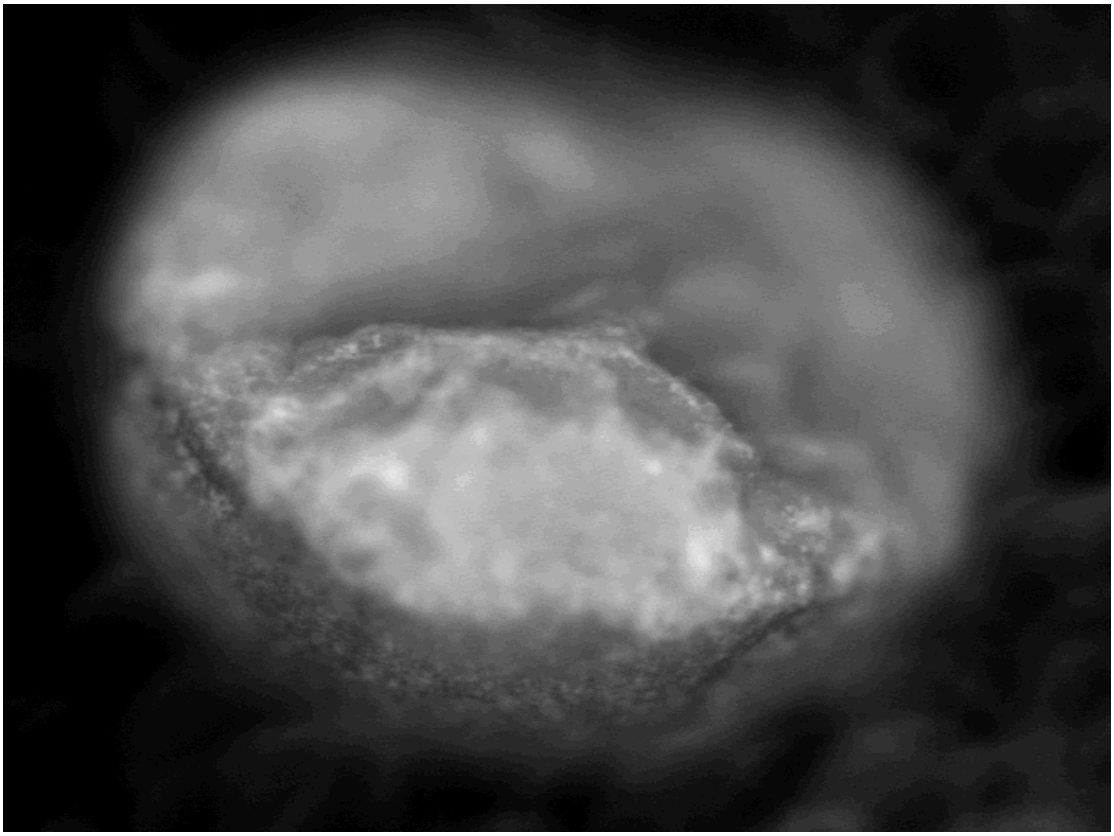


Image 2: Ball with focus on intermediate z level.

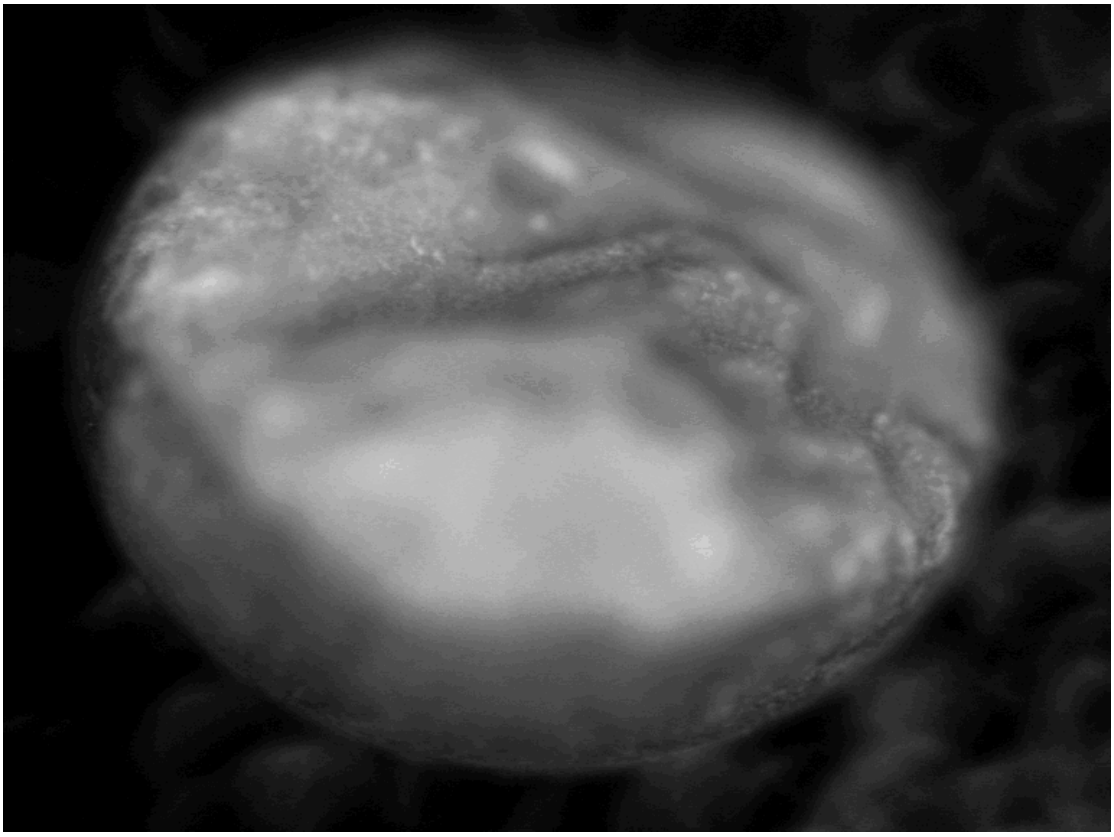


Image 3: Ball with intermediate focus a bit lower than for image 2.

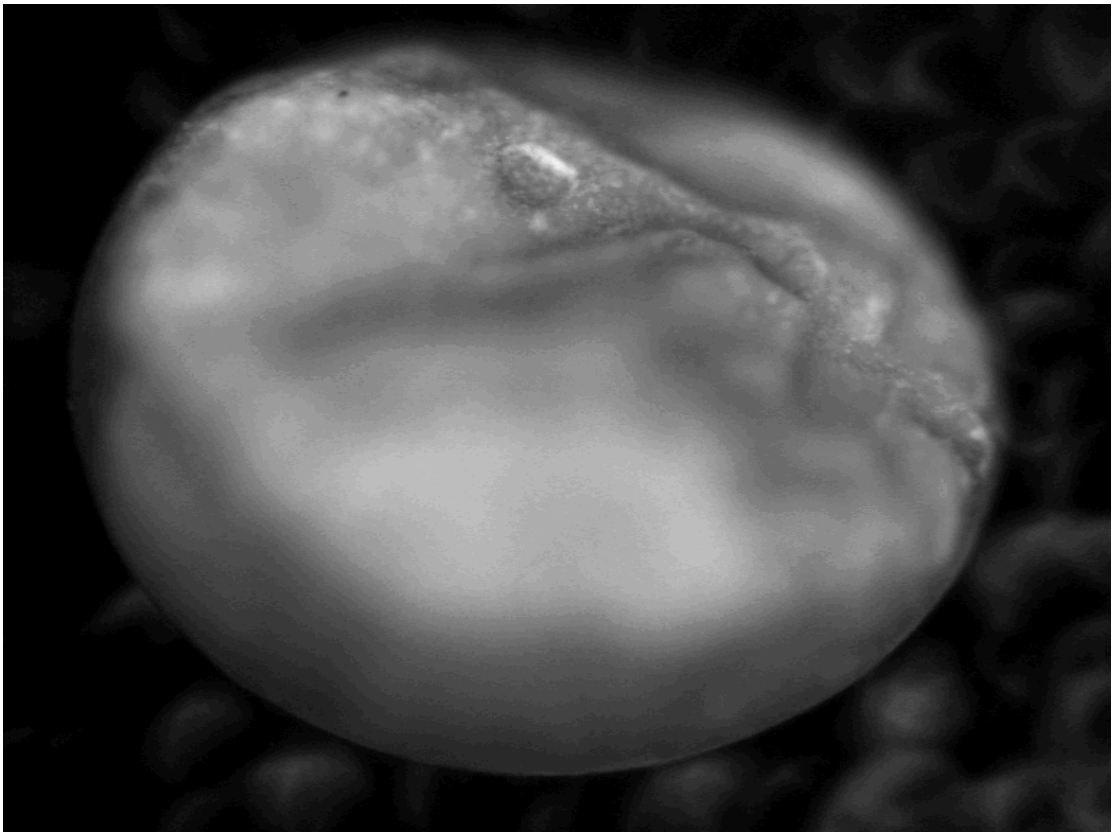


Image 4: Ball with intermediate focus a bit lower than for image3.

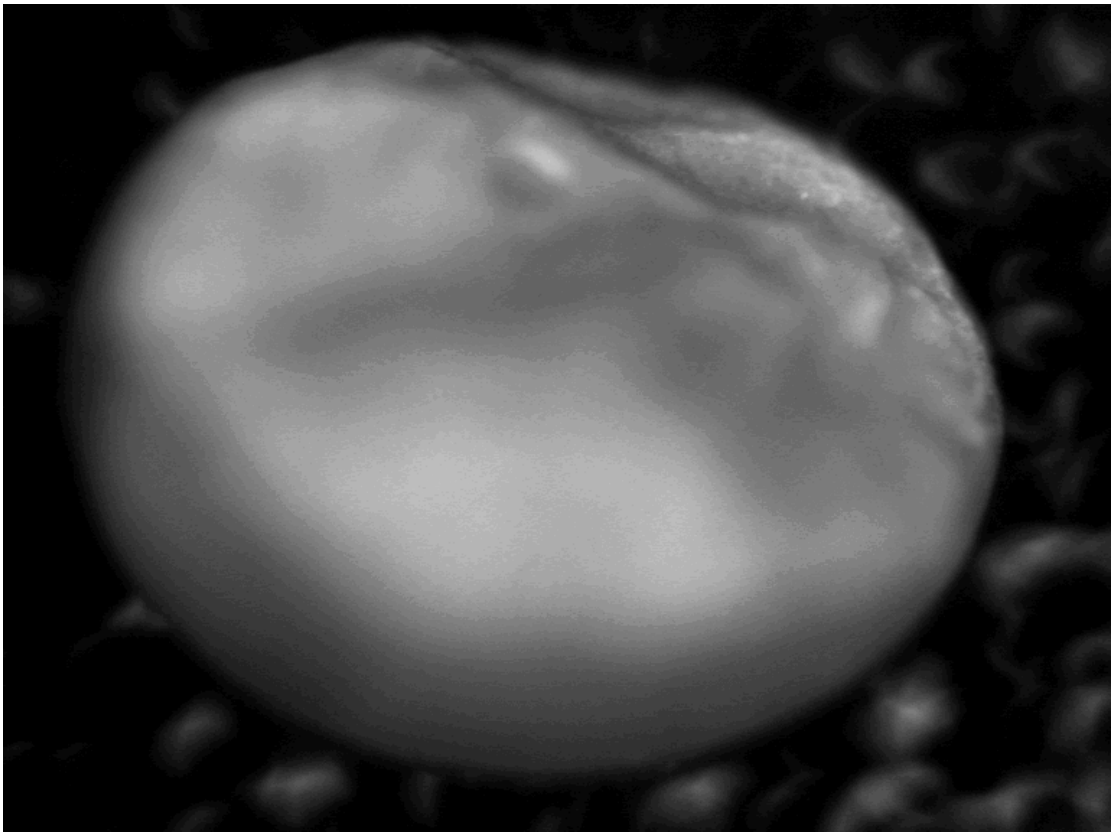


Image 5: Lower focusing plan (middle of the ball).

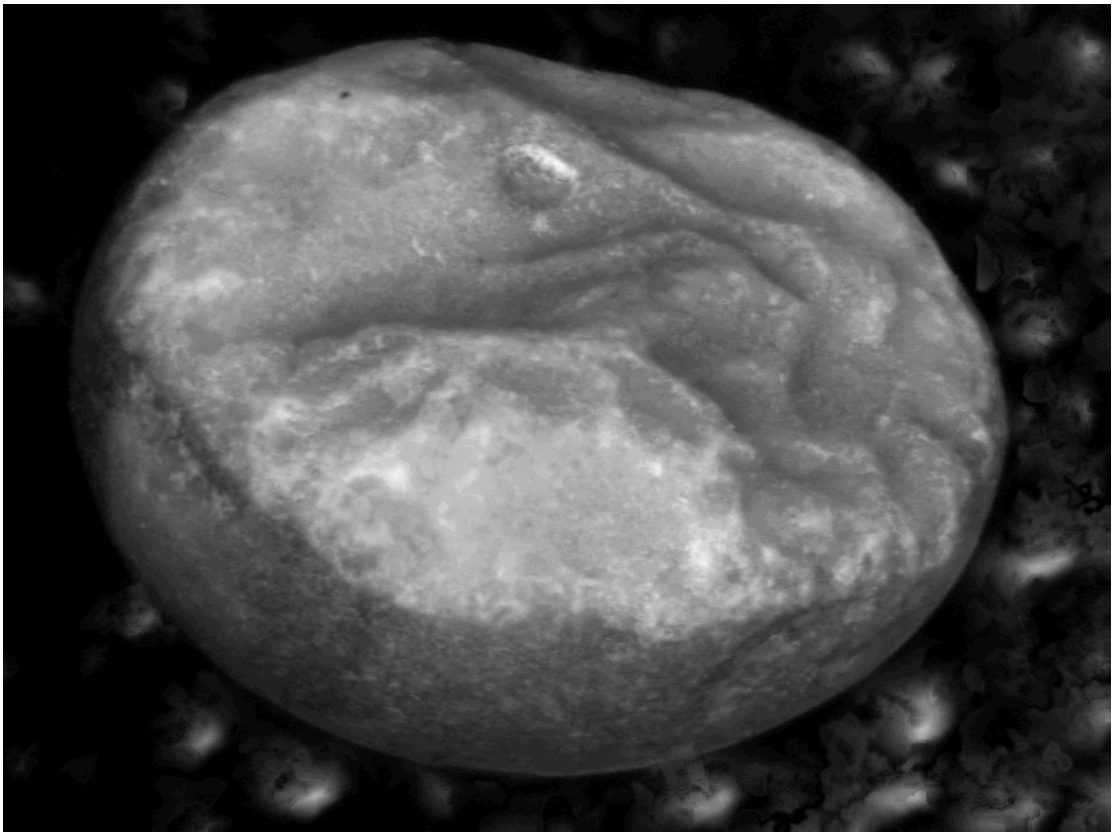


Image 6: Reconstructed image of the ball using the Multi Layer Grab instruction.

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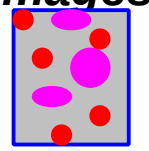
Image Analysis Report

Appendix B
Images



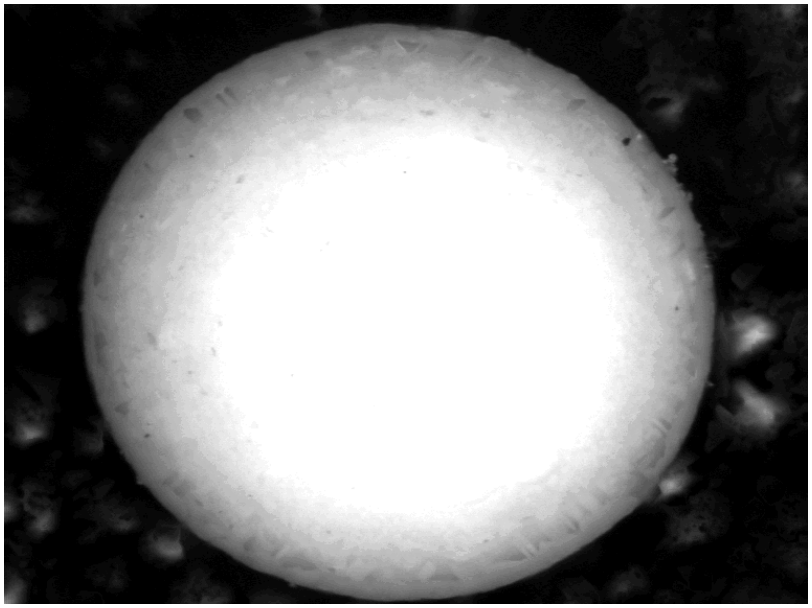


Figure 1 : New ball (50x).

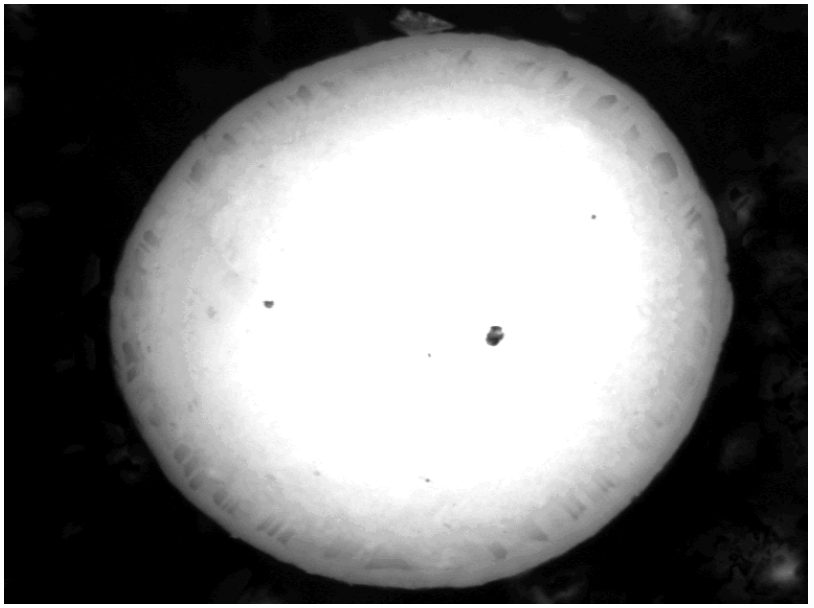


Figure 2 : New ball (50x).

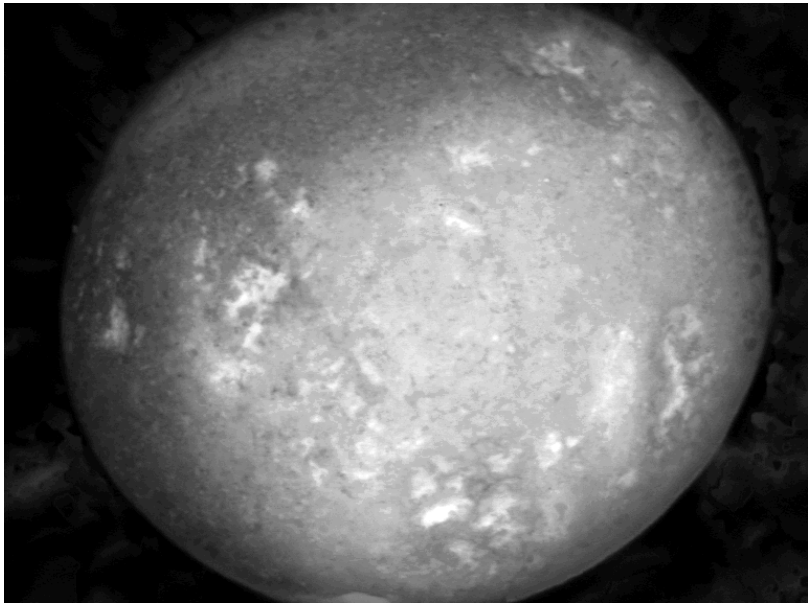


Figure 3 : Slightly worn ball (50x).

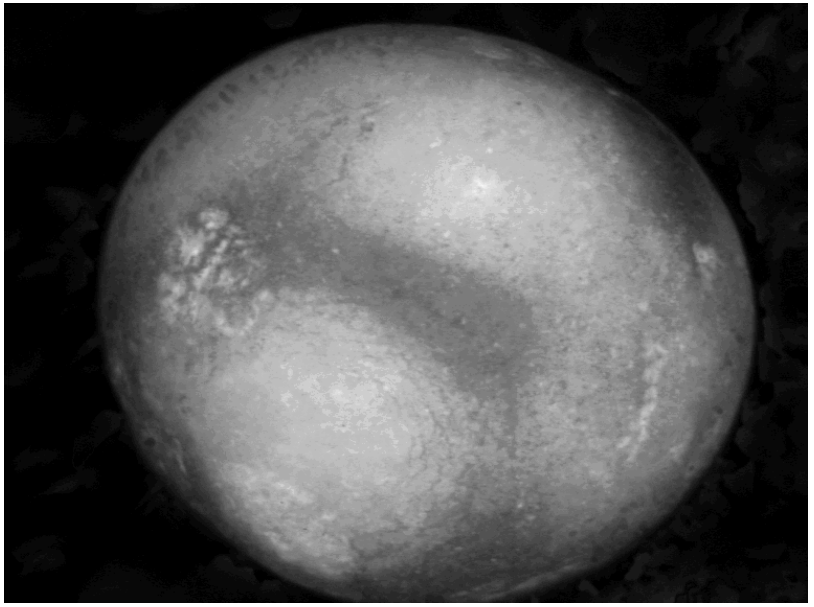


Figure 4 : Slightly worn ball (50x).

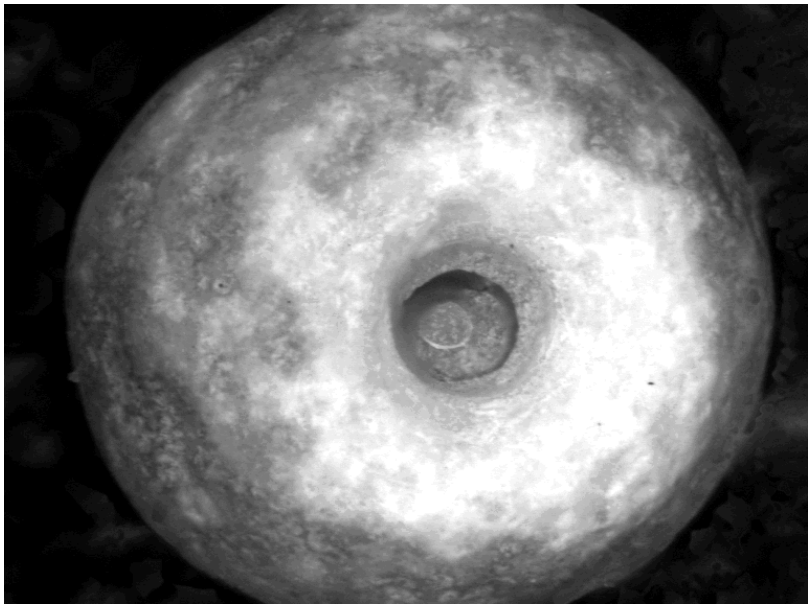


Figure 5 : Worn ball (50x).

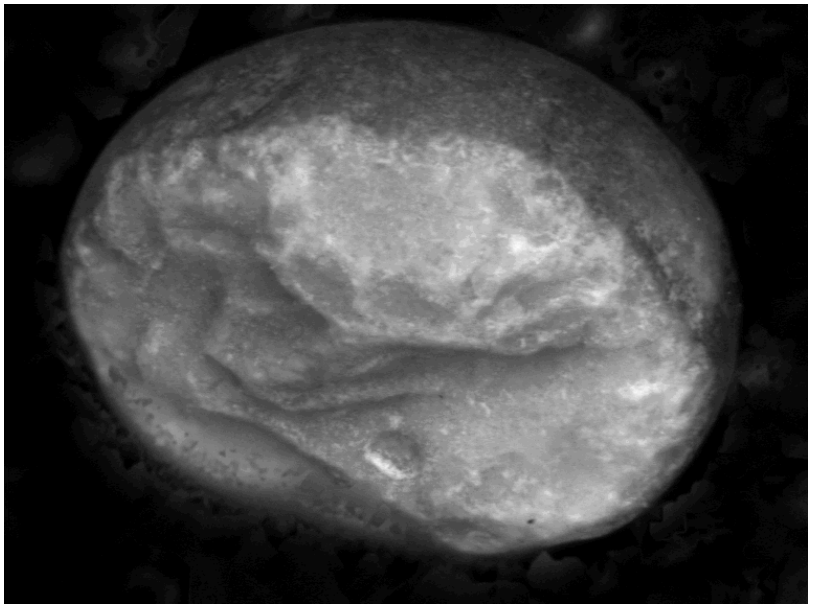


Figure 6 : Worn ball (50x).

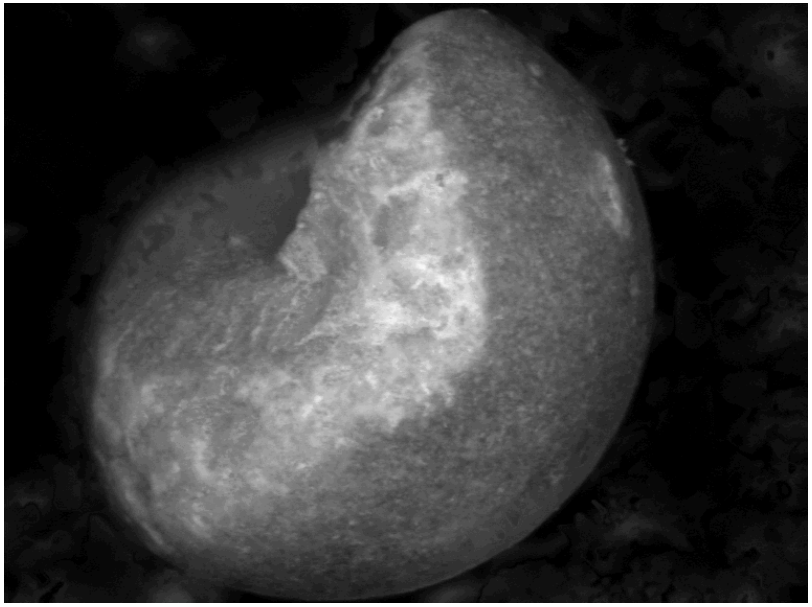


Figure 7 : Fragmented ball (50x).

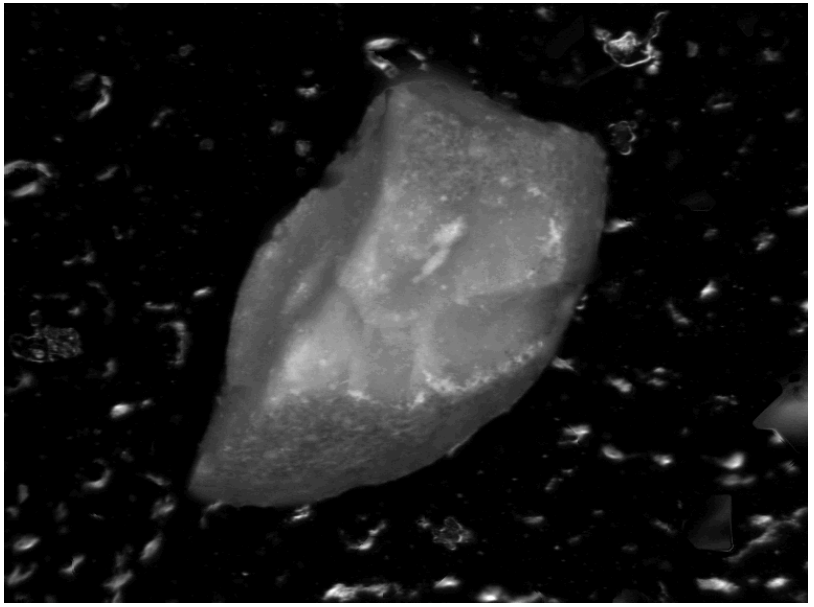


Figure 8 : Fragmented ball (50x).