3D Characterization of Iron Ore Pellets by X-rayMicroCT

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Introduction

Iron ore pellets, together with lump iron and sinter, comprise the mixture of iron ores which feed the blast furnaces in the production of primary iron. Due to large-scale production, microscopic characterization is an important step in quality control, allowing the identification of key factors which might be linked to the behavior of those materials during the process. Porosity characterization, for instance, directly determines the physical and metallurgical quality of the pellets. Pellets must remain porous to allow gas permeability during iron reduction, while maintaining compression resistance to withstand stresses due to transportation and in the furnace bed. During the pelletizing process, which involves high temperature phase transformations, cracks may also appear, with detrimental consequences to mechanical properties [1].

Traditionally, pellets are characterized by Optical Microscopy (OM) [2] or Scanning Electron Microscopy (SEM) [3]. Pore size distribution, in 2D, and phase fractions, can be obtained, after careful and lengthy specimen preparation steps. Mercury porosimetry is used to measure the volume distribution of open voids, but cannot sample closed pores or cracks, which are also relevant.

In this work, a 3D characterization methodology based on X-ray MicroCT was developed to discriminate, visualize and measure closed pores and internal cracks in iron ore pellets.

Materials and Methods

No specimen preparation was necessary except for gluing the entire spherical pellet on an aluminum tube to eliminate specimen drift during MicroCT scanning.

The X-ray microtomograph used in this work was the Zeiss-Xradia Versa 510 with a set of objective lenses. The acquisition conditions were: 150 kV voltage, 10 W power, 0.4X objective lens (macro lens) and exposure time of 7 s. The pixel size obtained in the particular geometrical configuration of source and lens was 7 µm. 4000 projections were obtained and reconstructed to generate 2D slices of the sample. A typical 2D slice of an iron pellet and a 3D render model are shown, respectively, in Fig. 1a and Fig. 1b

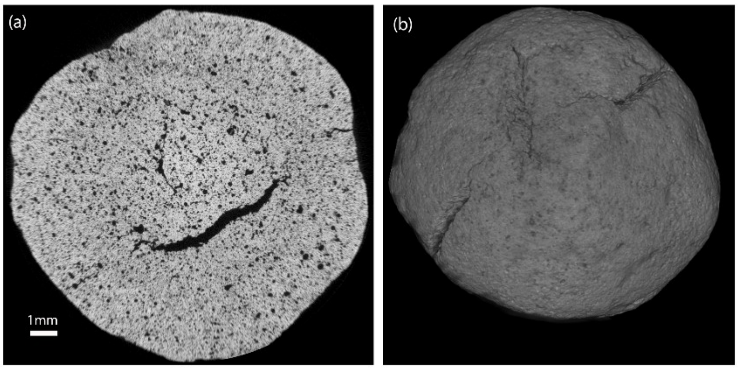

Figure 1. (a) 2D Slice; (b) 3D model.

ORS Visual SI (v. 1.8.0.1913) software was used for image processing and analysis. The image processing steps were as follows (See Figure 2): (a) Noise reduction with a 2D Non-local means filter (radius=3); (b) Segmentation of the solid phase; (c) 3D hole filling; (d) Subtraction (c-b) to obtain internal pores and cracks; (e) Size and shape classification.

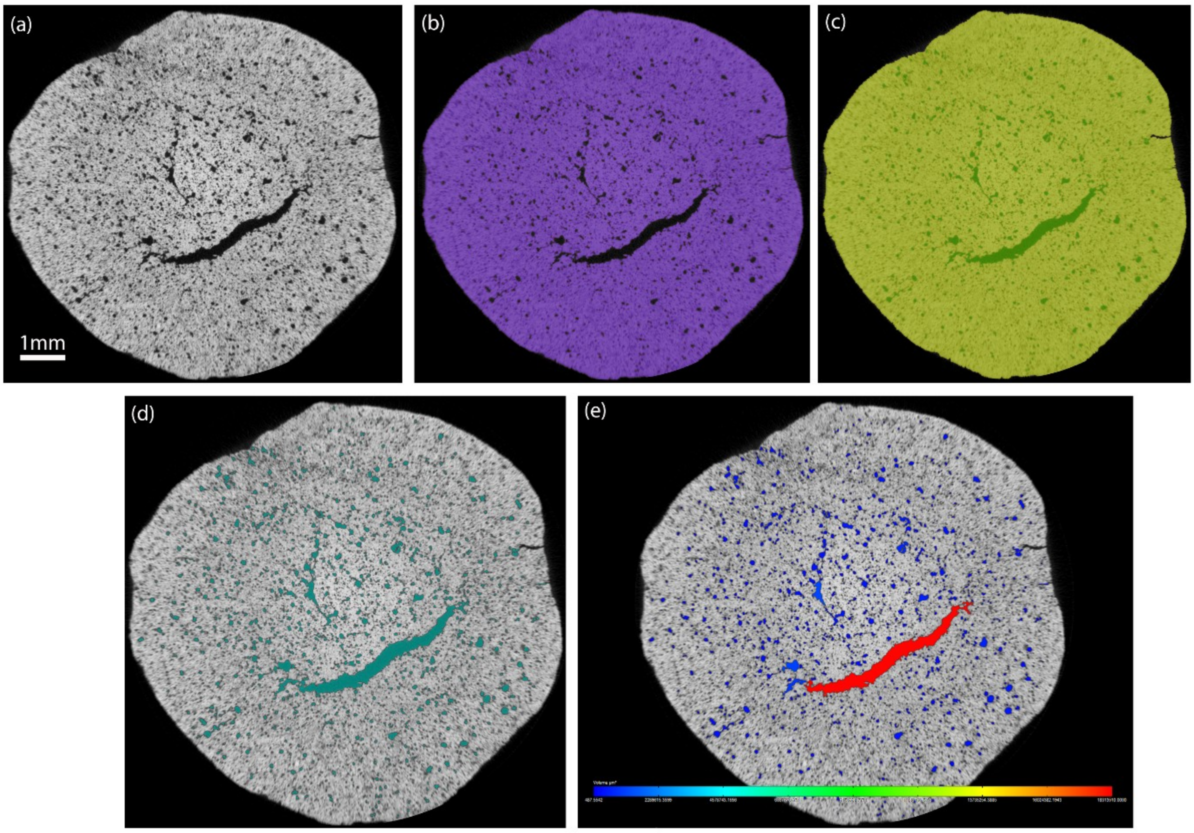

Figure 2. Image Processing Sequence. (a) Denoising with non-local means filter. (b) Segmentation of solid phase. (c) 3D hole filling. (d) Subtraction (c-b) to detect internal voids. (e) Size and shape classification.

Results and Discussion

Fig. 3 shows volume measurements of pores and cracks. Figs. 3a, b and c show, respectively, the XY, XZ and YZ planes. Fig. 3d shows a 3D visualization of pores and cracks color coded by volume value. Fig. 3e shows the volume distribution.

Fig. 3e makes it evident that very large objects exist (in red), which might be associated with cracks. In Fig. 3d only pores (in blue) can be seen, indicating that the cracks are surrounded by pores and, therefore, are in the center of the pellet.

Fig. 4 shows aspect ratio (AR) measurements of pores and cracks. (a, b and c correspond to XY, XZ and YZ planes, respectively. Again, shape differences are visible and can be linked to pores and cracks. Object filtering to a specific AR range, Figs. 4d and 4e, helps to confirm the fact that cracks are confined to the center of the pellet, as shown in the 3D model of Fig. 4f.

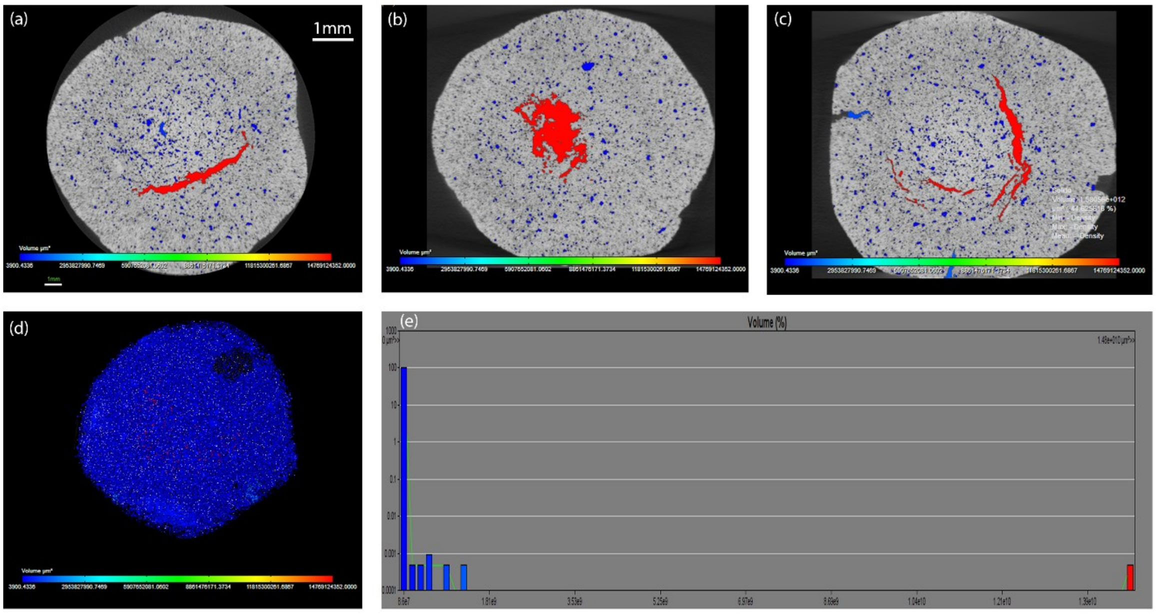

Figure 3. Color coded volume measurements. (a, b,c) XY, XZ, YZ planes. (d) Volume rendering. Peripheral small pores hide internal cracks. (e) Volume distribution.

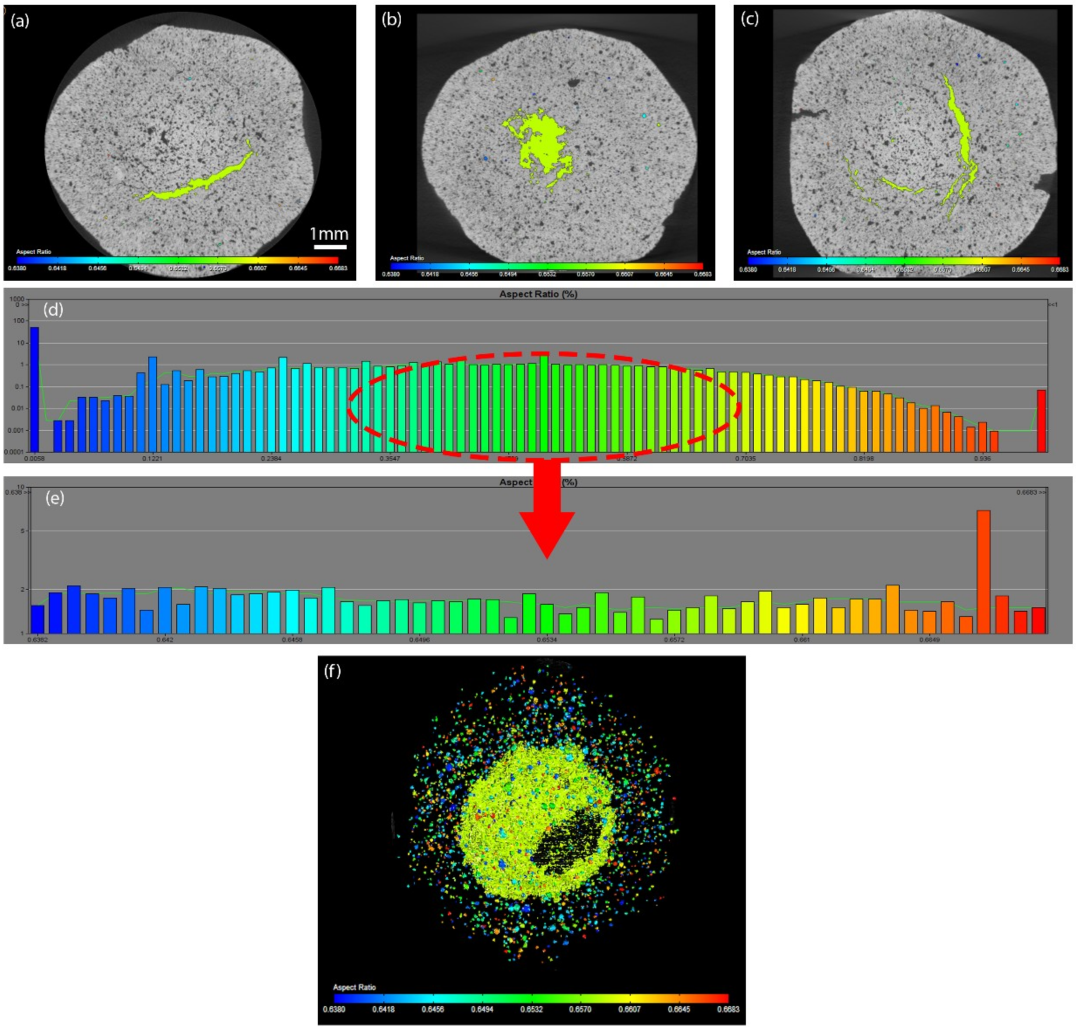

Figure 4. Color code AR measurements. . (a, b,c) XY, XZ, YZ planes. (d) AR distribution. (e) 0.6380<AR<0.6683. (f) Objects filtered by AR. Internal cracked surface is visible.

Conclusions

A methodology for characterization of pores and cracks in iron ore pellets was developed. After suitable image processing, internal voids were segmented and measured.

Volume and shape distributions were obtained. Even though AR is not the ideal shape discriminating parameter, the combination of measurement distributions allowed discriminating between pores and cracks. The global shape and location of cracks was revealed.

It is possible to connect the results with physical and metallurgical properties of iron ore pellets, which might be associated to their manufacturing process and impact iron reduction upstream.

Future work will evaluate open and closed porosity and compare results with traditional techniques such as Hg porosimetry.

References

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