Digitalizing the Mining Industry - 3D Scanning of Core Trays to Produce Volumetric Bulk Densities

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SUMMARY

Geological drill core samples can be digitalized using the Minalyzer Core scanner. Data sets generated from this scanning include XRF geochemistry, high-resolution images, specific gravity, RQD, structural logging, and sample topography. While all these data sets are useful for geologists, the sample topography has been increasingly beneficial for the iron ore industry. These models can be used to derive the sample volume, making it possible to generate the bulk density of the a sample in a fast and automated way as an alternative to the Caliper method. The error is ranges between 0.01-0.025 g/cm^3 depending on how competent or fractured the core is, making it a reliable and objective method.

Key words: Core Scanning, Digitalisation, Bulk Density, Volume, Fractured Core, Competent Core, XRF, Core Images.

INTRODUCTION

Scanning and digitalisation of geological samples such as drill cores have become more accepted in recent years. This article will focus on how digitalization of drill core can provide data that could impact not only the way the industry access, view, and work with the data, but also novel ways in which traditionally acquired data could be improved to solve current problems.

The Minalyzer Core Scanner (Minalyzer CS or CS) will be introduced and the datasets acquired will be briefly discussed.

In addition, the use of the 3D-topology model has proven useful in another application within the geological field, namely, to derive the bulk density of a sample through a novel procedure that will be described in this article.

There are several ways in which bulk density and specific gravity could be acquired. A range of methods include Caliper, Wax Immersion, Wax-shrink Wrap Immersion, Saturated Surface Dry, Helium Pycnometer and Water Immersion according to Crawford (2013).

While the Caliper method has several advantages such as the calculations being relatively simple, the equipment used is relatively inexpensive and more importantly the Caliper method will not cause any permanent damage to the core. Another benefit of the Caliper method is also that it could be measured on half core according to Scogings (2015).

The major drawbacks include, that the core needs to be cut into a geometric shape to properly determine the volume. It is easy to fit a competent core to a cylinder but if the core is heavily fractured or very angular this could be difficult to achieve according to Crawford (2013).

Scogings (2015), concludes that poor quality bulk density measurements lead to unreliable tonnage estimates which negatively affects mine scheduling and reconciliation of mineral production against reserves, and further concludes that determination of sample mass is easy, but the difficult step generally lies in trying to determine the volume of a sample. The ability to accurately assess the volume of a sample is vital, since most natural objects do not fall in perfect geometrical shapes, according to Crawford (2013), who concludes that the greatest limitation of the current methods is the aspect of human error that will always be present.

This article will introduce and explain the novel volume bulk density method and will determine the accuracy and repeatability and compare to the Caliper method.

MINALYZER CORE SCANNER

The Minalyzer CS is a geological sample scanner which in a contactless non-destructive way generates geochemistry, high-resolution images, rock quality designation (RQD), planar structural measurements, specific gravity and bulk density for drill cores and other geological samples. The scanner has previously been described in detail by Sjöqvist *et al.* (2015).

The workings of the scanner described in patent Blomdahl *et al.* (2011), is designed for handling large volumes of drill samples and is capable of scanning drill cores directly in core trays. It further describes the use of a laser technique generally referred to as Light Detection and Ranging (LiDAR), through which a 3D-model of the topology of the core and trays are generated, enabling the control and precision of a continuous X-ray Fluorescence (XRF) scanner head. The generated 3D model constitutes a central dataset that apart from guiding the XRF, also is used to calculate the RQD and sample volumes. Measurement of structural features can also be derived based on the 3D-model as described in another patent Artursson *et al.* (2017). Collecting the 3D-model takes roughly 1 minute per tray as part of the pre-scan procedure. The Minalyzer CS is presented in Figure 1.

Figure 1. The Minalyzer CS operating in a core shed.

CALIPER VOLUME METHOD

In the case of the Caliper method a pair of calipers are used to measure the core diameter at a set of points along the core sample in order to get an average core diameter for the sample. This is followed by measuring the core sample length using a tape measure or ruler according to Scogings (2015). Crawford (2013) used a similar approach but also measured an average length of core.

The sample is then weighed. In the case of core positioned in a core tray, the whole core tray is weighed first empty, and then with material in it. Care should be taken to either physically or numerically remove the weight of any artifacts that do not constitute the geological sample of interest, such as distance markers or core blocks indicating drilling depth and direction.

Having collected the measurements as well as the weight the next step is to calculate the volume that the material constitutes in the shape of a cylindrical core by using the equation for determining the volume of a cylinder according to Equation 1 (Geometric Volume).

Equation 1:

$$V = \frac{\pi * L * D^2}{4}$$

Where:

V = Volume of the sample in cm^3
D = Average diameter of the sample in cm
L = Length of the sample in cm

In turn, the bulk density is calculated using Equation 2.

Equation 2:

$$\rho = \frac{W}{V}$$

Where:

ρ = Density of the sample in g/cm^3
W = Weight of the sample in g
V = Volume of the sample cm^3

VOLUME BULK DENSITY METHOD

The volume bulk density method is in large based on the Caliper method. The big difference that the volume is not manually calculated but rather derived from the use of the 3D-model (scanned volume) acquired as part of the digitalization scanning process. The method is designed to be applied per core tray but can be adapted to work with other samples and containers as well.

First the tray containing the sample is weighed. It is important that any artifacts are removed from the tray to get the weight of the sample only. The weight of an empty tray should be subtracted from the measured weight to derive the sample weight.

The next step is defining a reference geometry either by approximation or by scanning a tray geometry in the Minalyzer CS.

The volume is derived by determining the average height in a raster on both the reference geometry as well as the sample geometry in the relevant parts of the tray. The difference between a point in the reference geometry and the sample geometry is the integrated volume of the sample at that point. Performing this exercise over the tray will generate the volume of the total sample in the tray.

Having derived the weight and the volume, the density of the sample can be calculated using Equation 2.

METHOD REPEATABILITY

The repeatability of the volume bulk density method will be demonstrated by repeatedly weighing and scanning core trays containing different competency of core, one tray with mainly competent core and one with mainly highly fractured/broken core. The test will be conducted 10 times per tray and any highly fractured core sections will be altered and moved between each repeat in order to see how the density might vary.

The error will be determined as half of the range between the highest and the lowest value according to Equation 3.

Equation 3:

$$E = \frac{X_{max} - X_{min}}{2}$$

Where:

E = The range error
X_{max} = The highest value of the range
X_{min} = The lowest value of the range

METHOD ACCURACY

The accuracy will be determined by applying the method on a prepared reference tray with known cylindrical shape and weights. The tray consists of samples made out of a plastic PVC pipe of known diameter of 90 mm and length of a total of 1m cut into four sections of varying length. Each section has been filled with sand of different amounts and sealed off at each end. The sections have then been weighed separately. The bulk density of the reference material has been measured to be 1.33 g/cm^3. The reference tray is presented in Figure 2.

Figure 2. A sample reference tray developed for testing the accuracy of the method.

The accuracy will be determined by retrieving the volume and calculate the density based on the total weight of the samples which is measured to 8.46 kg.

RESULTS

Two different trays were selected and scanned. A 3D-representation of the two trays A and B is visible in Figure 3

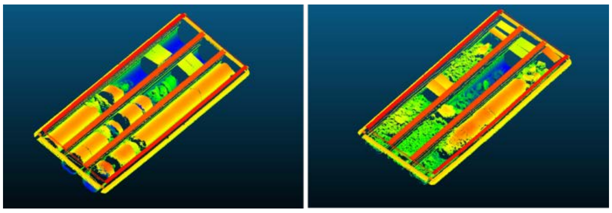

Figure 3. A 3D representation of the two trays, A (left) and B (right) used in the repeatability study.

The results as collected for tray A from 10 measurements is presented in Table 1. An image showing the difference between the runs for tray A is presented in Figure 4
.

Table 1. Results acquired from tray A.

Run	Core Weight [g]	Volume [cm^3]	Density [g/cm^3]
1	18420	8961.50	2.06
2	18420	9037.76	2.04
3	18420	9050.09	2.04
4	18420	8982.55	2.05
5	18400	9032.28	2.04
6	18420	9016.47	2.04
7	18420	8988.10	2.05
8	18400	9008.01	2.04
9	18420	8996.65	2.05
10	18400	8983.25	2.05

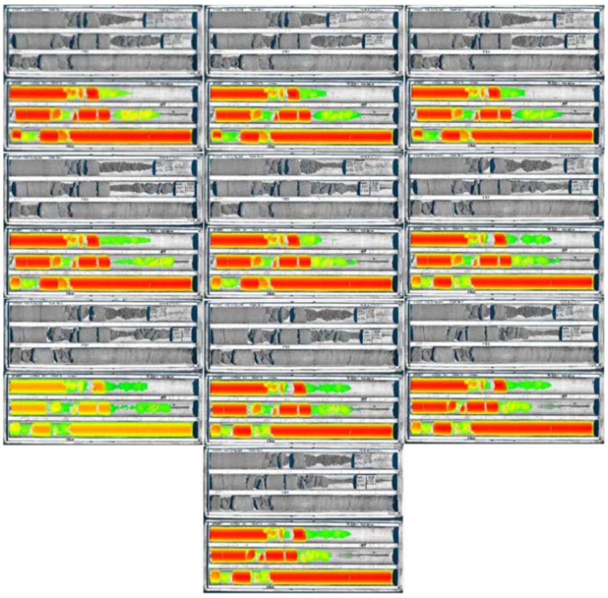

Figure 4. The topographic image depicting each run in consecutive order starting from top to bottom, left to right. Top tray in the pair is the original tray and the bottom is the volume that have been identified as a heat-map based on height.

The results from both tray A and tray B with the calculated range error is presented in Table 2.

Table 2. The bulk density for each run for tray A and tray B,

	Tray A	Tray B
Run	**Density [g/cm^3]**	**Density [g/cm^3]**
1	2.056	1.820
2	2.038	1.770
3	2.035	1.780
4	2.051	1.780
5	2.037	1.790
6	2.043	1.800
7	2.049	1.770
8	2.043	1.820
9	2.047	1.810
10	2.048	1.820
Range	0.020	0.050
Error	0.010	0.025

The data from scanning of the reference tray provided a volume of 6 335 cm^3 which correspond to a bulk density of 1.34 g/cm^3. Solving the length in Equation 1 based on the volume from the topographic measurement gives a length of 1m. The data is presented in Figure 7.

APPLICATION IN INDUSTRY

In the Pilbara region in Northern Western Australia, geotechnical core samples are routinely extracted from which bulk density is measured and calculated using the Caliper method. The geology in the area makes the samples highly friable and often present themselves in a broken state. An Australian Iron ore company operating in the Pilbara region scanned 300 trays and compared the scanned volume against the geometric volume derived from the Caliper method. The results from a comparison of these results are presented in Figure 5.

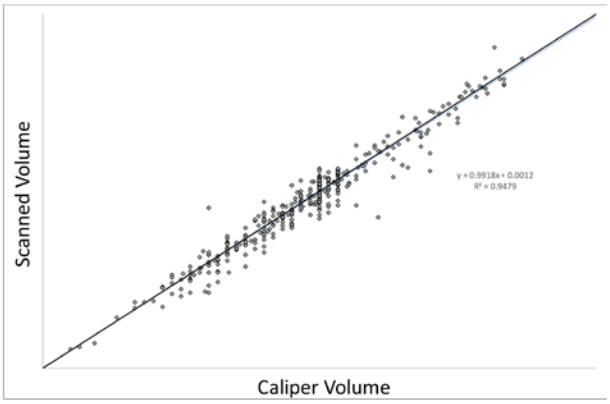

Figure 2. Correlation plot between the Caliper method and the Volume Bulk Density method.

The correlation is extremely consistent between the two data sets however a few patterns arise from.

1) Vertical lines can be seen in the graph which means there is the same Caliper volume for varying scanned volumes. This indicates a rounding of the core length in the core trays to the closest 5 cm reducing the accuracy of the geometric method.

2) The scanned method is also slightly higher than the Caliper method on average. The explanation for this is due to the laser capturing the topology of the core from above the material it assumes a solid volume under all the measured points. Therefore, any void space is included in the volume of the material.

The comparison was further broken down to group the data into three different material types: Competent (greater than 75% competent core), Mixed (30-75% competent core) and friable (<30% competent core). Figure 6 shows the variation between the geometric and scanned volumes for each material type. This shows the high variation in the friable and mixed trays in comparison to the competent. The Minalyze scan method is tighter/matches better with Competent core, in comparison to the less easily “geometrically measured’ mixed/friable material.

CONCLUSIONS

The results show that the error on repeatability in the competent type core is 0.01 g/cm^3 which agrees with what Crawford (2013) reports, who got the same error of 0.01 g/cm^3 on competent pieces of core using the Caliper method. The fractured/broken core tray shows an increased error of 0.025 g/cm^3 which is still considered low. Therefore, for any scanned cores using this method it is assumed the error is between 0.01 – 0.025 g/cm^3.Crawford (2013) mentions that the Caliper method gave severely worse results on the slag type of core, it was not mentioned by how much the variation increased.

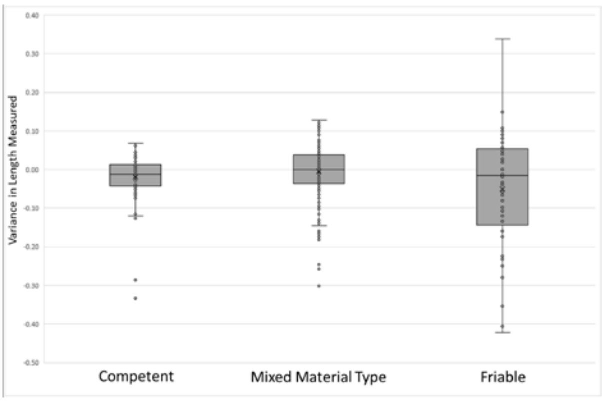

Figure 3. Groups of core competency as: Competent (left), Mixed Material Type and Friable (right) and the respective error bars.

The increase in error for the scanned method is due to the laser capturing the topology of the core from above the material and assuming a solid volume under all the measured points, meaning that the technology is not considering any void spaces between or under the fractured pieces. Since the volume is expected to be slightly higher due to this effect, the resulting bulk density value will be underrepresented or conservative. This error can be mitigated by correct preparation of the core before it is scanned to create as little void space as possible.

The method performs well in terms of accuracy, as the difference in bulk density on measuring the reference tray than compared to the real bulk density was only 0.01 g/cm^3, which confirms the error measured in the repeatability study.

The application of the scanned volume method on Pilbara Iron Ore shows that the method compares extremely well to the Caliper method and is not susceptible to a rounding issue.The scanned volume shows a very low variance of 0.1cm for competent core pieces compared to the caliper method. This variance increase to 0.4cm for friable core which we would suggest is due to it being harder to measure using the Caliper Method.

Given the accurate data produced in this study the new volume bulk density method is a great complement or alternative to the range of other methods used to determine density and can produce consistent bulk densities on both competent and friable core material. Another aspect of this method is that it is objective and is less susceptible to human errors. Furthermore, it can be automated to a high degree speeding up the the time taking to obtain a measurement.

Future work studies should involve more samples of higher variety and more repeat runs of the reference tray should be performed to further evaluate the method.

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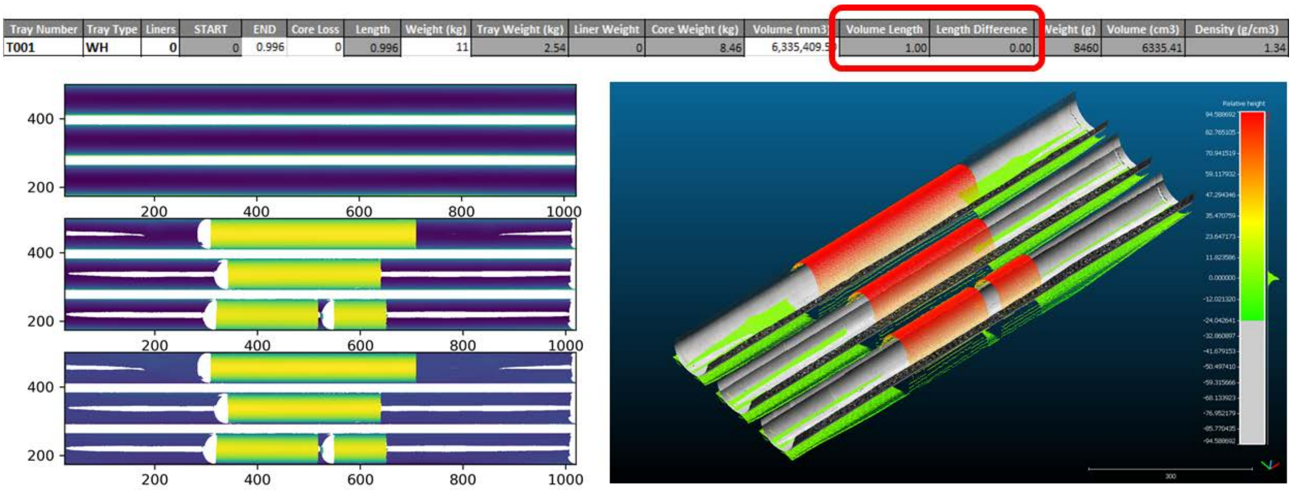

Tray Number	Tray Type	Liners	START	END	Core Loss	Length	Weight (kg)	Tray Weight (kg)	Liner Weight	Core Weight (kg)	Volume (mm3)	Volume Length	Length Difference	Veight (g)	Volume (cm3)	Density (g/cm3)
T001	WH	0	0	0.996	0	0.996	11	2.54	0	8.46	6,335,409.5	1.00	0.00	8460	6335.41	1.34

Figure 4. A summary of the results from scanning the reference tray (top), a heat-map of the volume against the reference geometry (bottom left) and the topographic data displayed (bottom right).