UQ Gas & Energy Transition Research Centre

QUANTIFYING COAL MECHANICAL PROPERTIES USING DIGITAL IMAGE CORRELATION METHOD

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Introduction

Coal is an anisotropic porous media constituted by coal matrix and complex cleat networks. Therefore, a coal geometry structure can be described by various parameters such as cleat network orientations, cleat length, aperture, spacing, density and connectivity. These parameters can significantly affect the mechanical properties such as Young's modulus and porosity in different surface regions of the same coal.

Objective

- Identify the mechanical properties and areal deformation of the coal sample surface
- Quantify the contribution of the coal's cleat, and matrix to the overall deformation using Digital Image Correlation (DIC) System
- Determine Young's modulus and cleat compressibility different between cleat and matrix region

What is DIC

DIC: A non-contact deformation and strain measurement technique

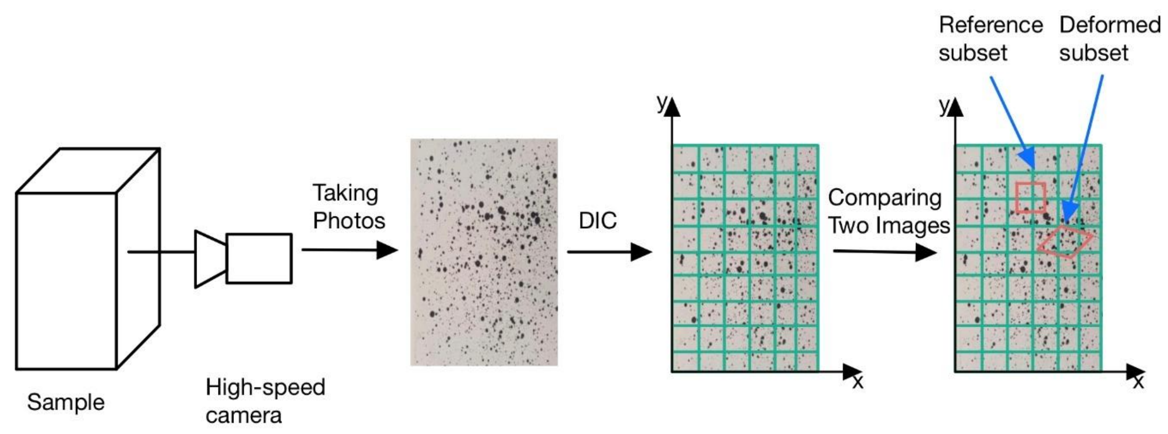


Figure 1. Digital Image Correlation (DIC) theory

Method

Sample Preparation

Prepared cubic samples with 45 mm dimension. Then, we apply two method to measure the surface deformation (1) Spray the sample using spray gun to generate speckle patterns for the DIC method (2) Draw dots on the sample for AVE non-contact extensometer analysis

Then we conducted cyclic uniaxial compression tests. Record the surface deformation of the coal sample using 2D-DIC and AVE extensometer.

DIC analysis

Conduct uniaxial compression test using the Instron machine. 2D-DIC and AVE extensometer are used to analysis the surface deformation. The AVE uses laser to analyse the strain between two dots. The DIC method records a video of the sample's surface and analyses the full-field strain.

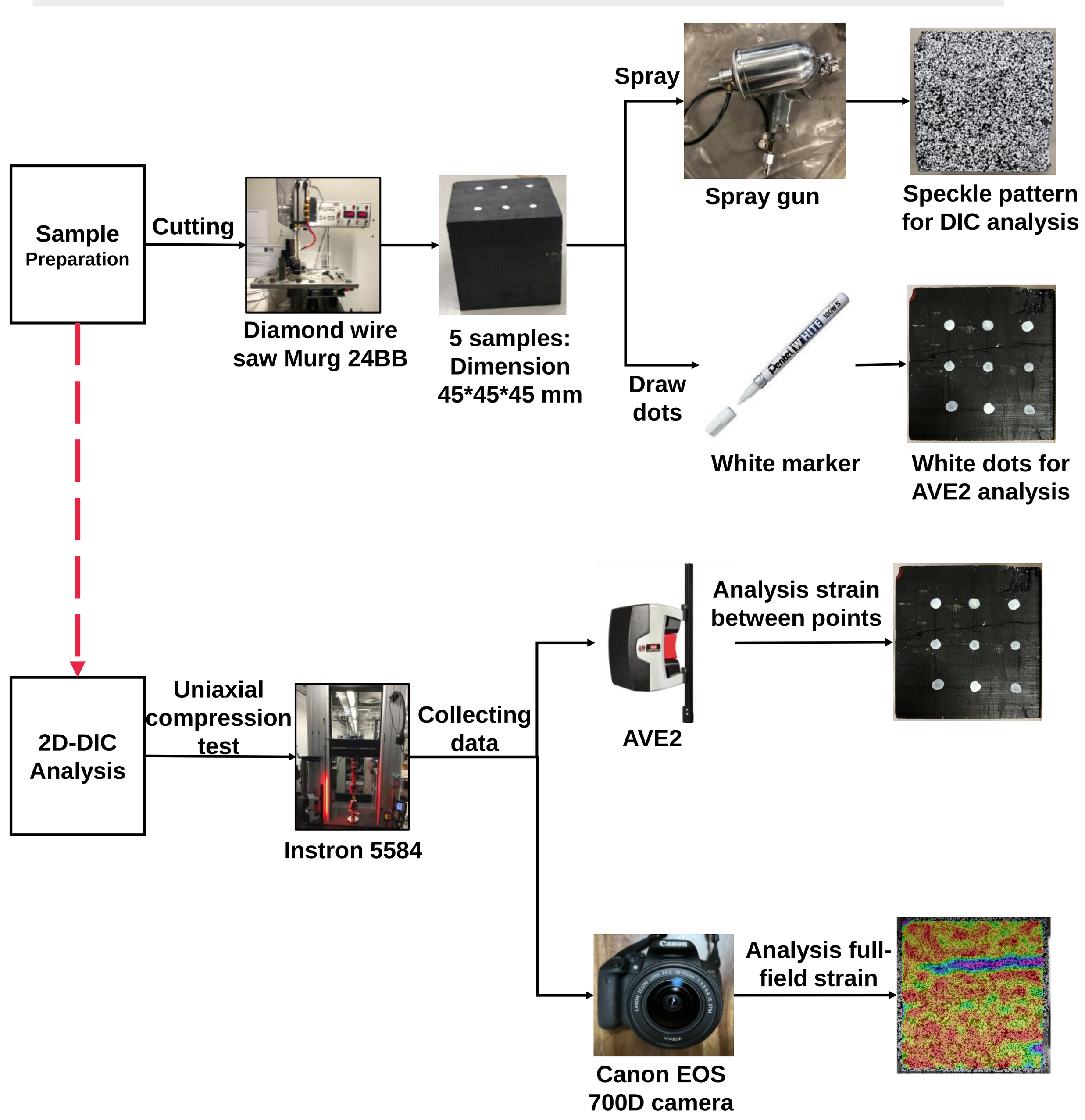


Figure 2. Methodology

Results

DIC vs. AVE

The accuracy of DIC is verified by comparing the results with AVE. The strain during the compression test is measured using the AVE and DIC method separately and matched according to their positions (Figure 3 (a) and (b)).

Figure 4 (a) summarised the average Young's modulus from the 5 loading cycles. It can be seen that, the Young's modulus of the cleat region is much lower than matrix region.

Figure 4 (b) shows the percentage difference between AVE and DIC method. All three regions show an acceptable percentage difference which is <20%, indicating the DIC method can accurately identify the surface deformation.

DIC strain calculation: The average strain $\epsilon_{yy\ average}$ within selected area as the sum of all the strain within the selected region divided by the number of data points.

$$\epsilon_{yy\ average} = \frac{\sum_1^n \epsilon_{yy}}{n} \qquad E = \frac{\sigma}{\epsilon} = \frac{\Delta\sigma}{\Delta\epsilon}$$

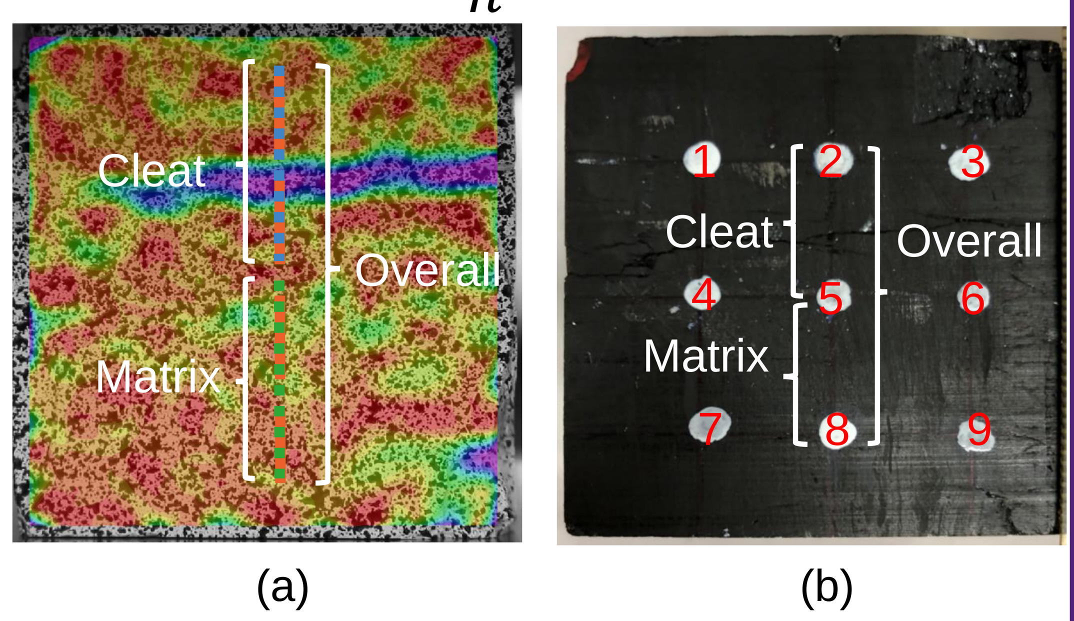


Figure 3. A typical example of how to match the DIC and AVE strain data (a) selected areas for DIC strain calculation (b) selected points for AVE strain measurement.

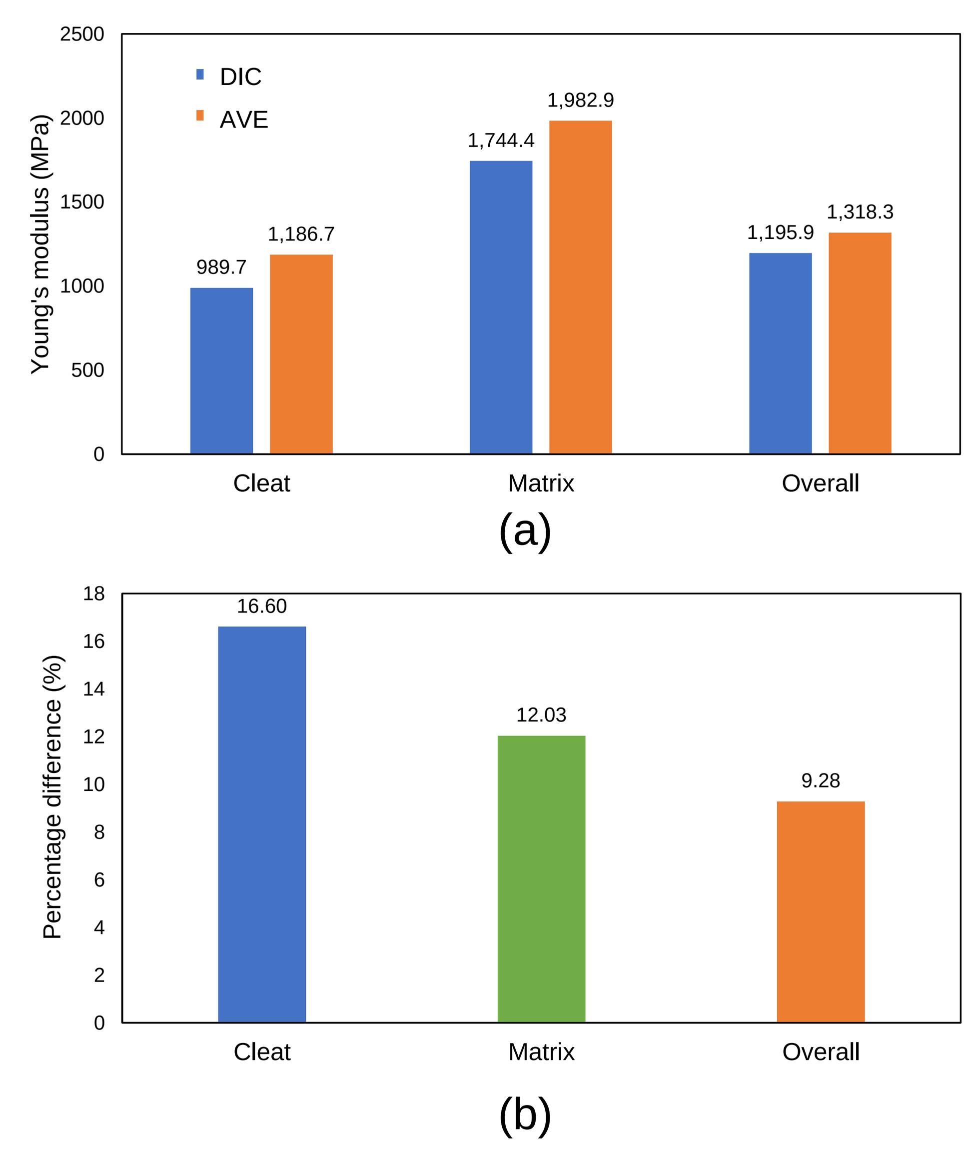


Figure 4. DIC accuracy verification (a) averaged Young's modulus calculated from DIC and AVE (b) Percentage deference of averaged Young's modulus between DIC and AVE

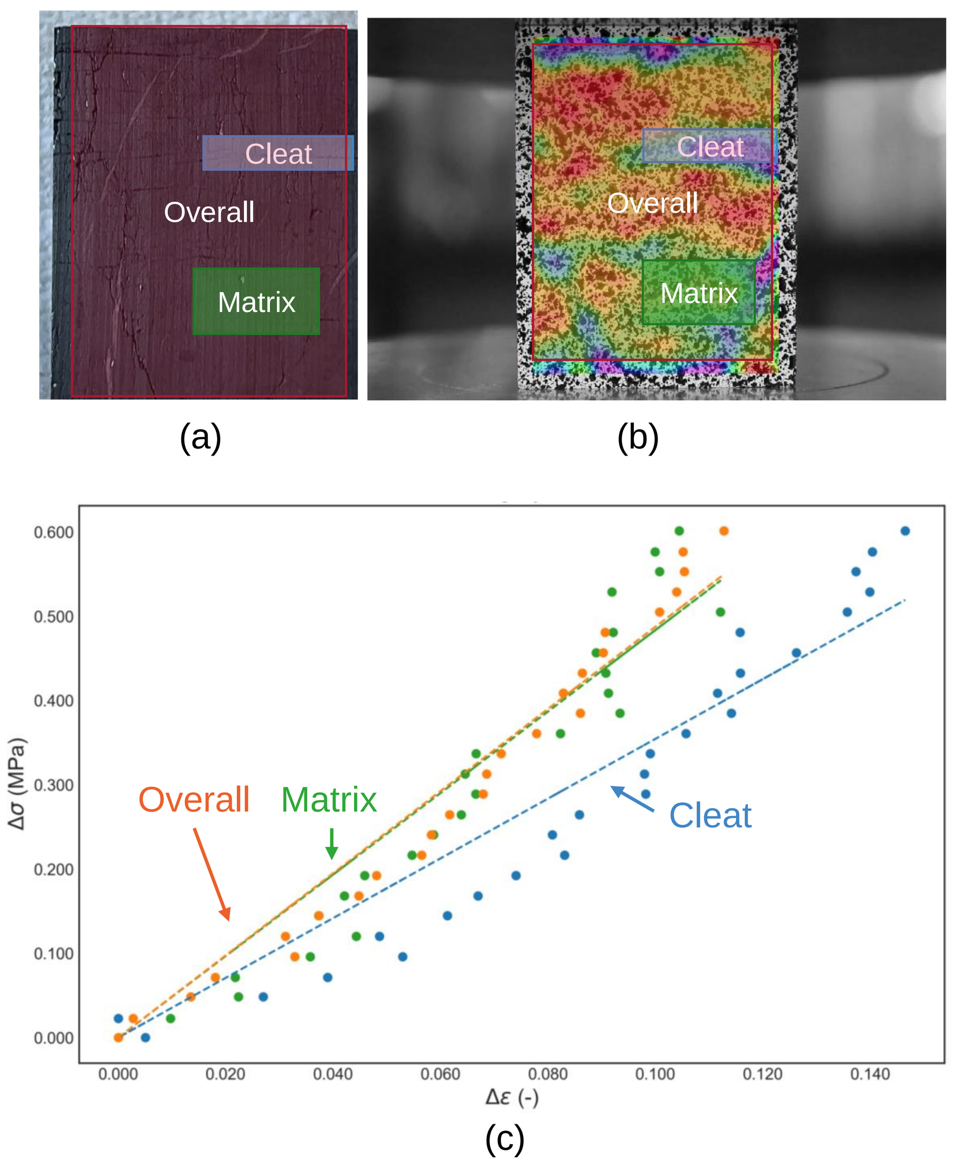
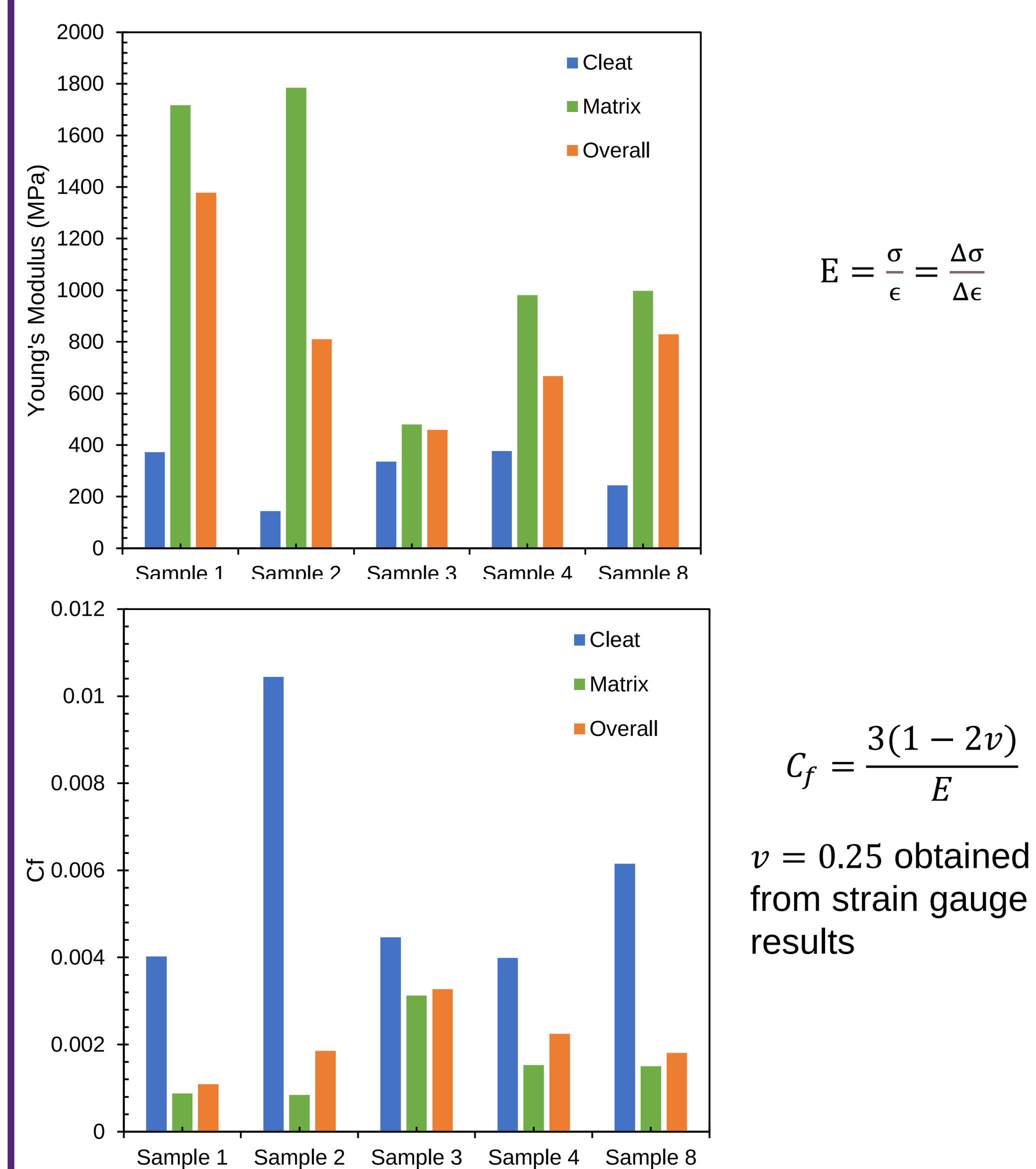


Figure 5: A typical example of how the cleat, matrix and overall areas are selected (a) photo of the sample, (b) full field strain contour from DIC and (c) stress-strain curve using strain data from selected area



$$E = \frac{\sigma}{\epsilon} = \frac{\Delta\sigma}{\Delta\epsilon}$$

$$C_f = \frac{3(1-2\nu)}{E}$$

$\nu = 0.25$ obtained from strain gauge results

Figure 6: Cleat vs. Matrix vs Overall (a) Young's modulus and (b) cleat compressibility for different samples

Comparison of Coal Compressibilities

In this poster, we quantify the strain from different regions (cleat, matrix and coal bulk) as illustrated in Figure 5 (a) and (b). Figure 5 (c) illustrates stress-strain curve using strain data from selected area. Figure 6 summarised the Young's modulus and cleat compressibility of samples. The cleat region has the lowest Young's modulus (and highest Cf), while the matrix region get the highest, suggesting that the Young's modulus can be significantly reduced by the fracture inside a specimen.

Conclusions

1. The accuracy of DIC is verified by comparing the results with AVE system
2. Average Young's modulus of cleat region are 294 MPa, matrix region are 1,192 MPa and overall region are 828 MPa. The ratio of E_{cleat}: E_{matrix} = 0.25
3. Cleat Compressibility varies from 0.004 to 0.01 for different samples
4. Average compressibility of cleat region are 0.0058, matrix region are 0.0016 and overall region are 0.002. The ratio of $C_{f\,cleat}$:$C_{f\,matrix}$=3.69

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