UNIVERSITY OF TYUMEN

Preliminary results

- Coal geomechanical properties -

Developed by:

Dr. Aleksandr Zhuravljov
Natalya Khoperskaya
Zakhar Lanetc

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1 Main research findings

1. The proposed correlation procedure allows to find the layer shift between two micro-CT images under different pressure conditions. In our case the Pearson's correlation is utilized, however, more sophisticated correlations might be applied. The correlation shape having one clear peak allows to precisely identify the layer shift.

2. Micro-CT resolution does not allow to determine coal geomechanical properties with the required accuracy. Trilinear interpolation is performed in order to increase micro-CT resolution by 10 times achieving the required accuracy of the final results.

3. Considering this particular research, the conventional calibration methods could not be applied as their potential computational error is too high. Thus, the new calibration approach is proposed based on the spatial variation of the calibrated sample in six directions (6 degrees of freedom).

4. In order to find the radial enlargement of the core sample, the artificial transformation of Cartesian grid system into the cylindrical one is performed.

5. Special package in C++ is developed allowing users to input two uncalibrated micro-CT experiments under different pressure conditions and easily obtain coal geomechanical properties, namely Young's modulus and Poisson's ratio.

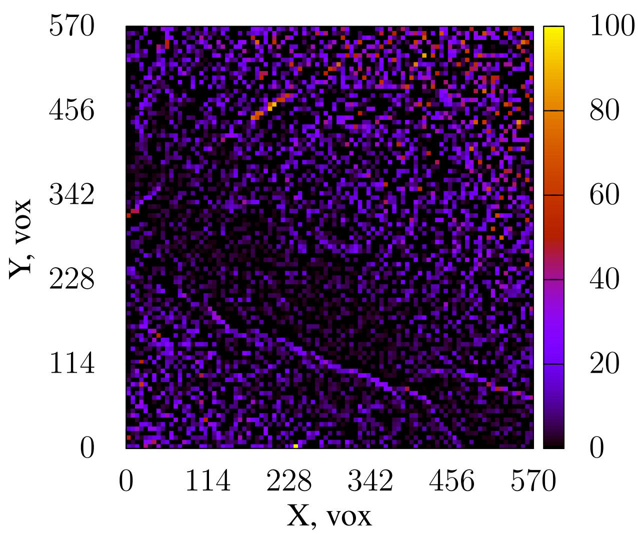
6. Using two experiments under $5,000\ psi$ and $10,000\ psi$, Young's modulus is found to be equal to $521,943\ psi$, while Poisson's ratio is equal to $0.139,377$.

2 Young's modulus determination

As the pressure applied at the core, it shrinks along its length. We then may assume that micro-CT layers follow the same trend during core shrinkage. If we compare two micro-CT images, for instance at $5,000\ psi$ and $10,000\ psi$, we should be able to find how the same layer from the one core side changes its location depending on the applied pressure. This is possible as we compare particular layer from the first micro-CT image with particular set of layers from the second micro-CT image.

If two layers at one side of two different micro-CT images under varying pressure conditions are equal, we may find the layer shift by looking at the number of voxels at different mciro-CT. Similar procedure is undertaken at the other side of the core sample (calibration) as the pressure is applied from the both sides. It is essential to utilize the calibration procedure as one core sample may slightly change its spatial disposition in two different micro-CT experiments. This fact leads to the occurrence of a moving front when particular layer from the first micro-CT image is subtracted from the set of layers from the second micro-CT image (see Fig.1). Having two micro-CT images calibrated and knowing the pressure difference between two experiments, the Young's modulus might then be found.

The length variation between two micro-CT images is found by analysing the Pearson's correlation coefficient (PCC), where its maximum shows the most possible location of the shifted layer (see Fig.2).



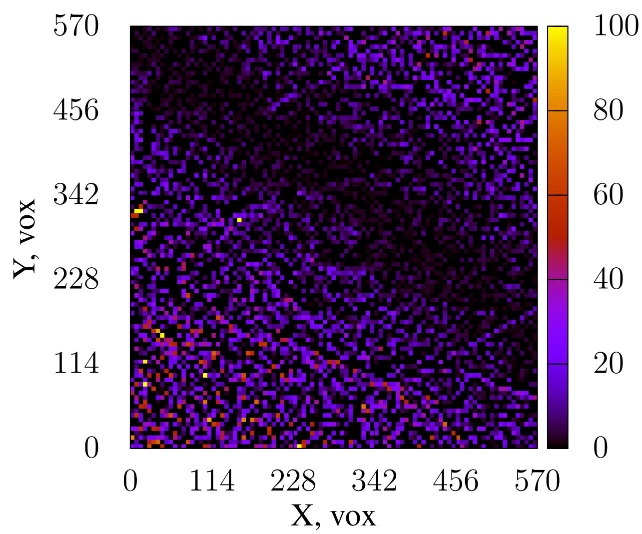


Figure 1: Occurrence of a moving front during the micro-CT layer subtraction.

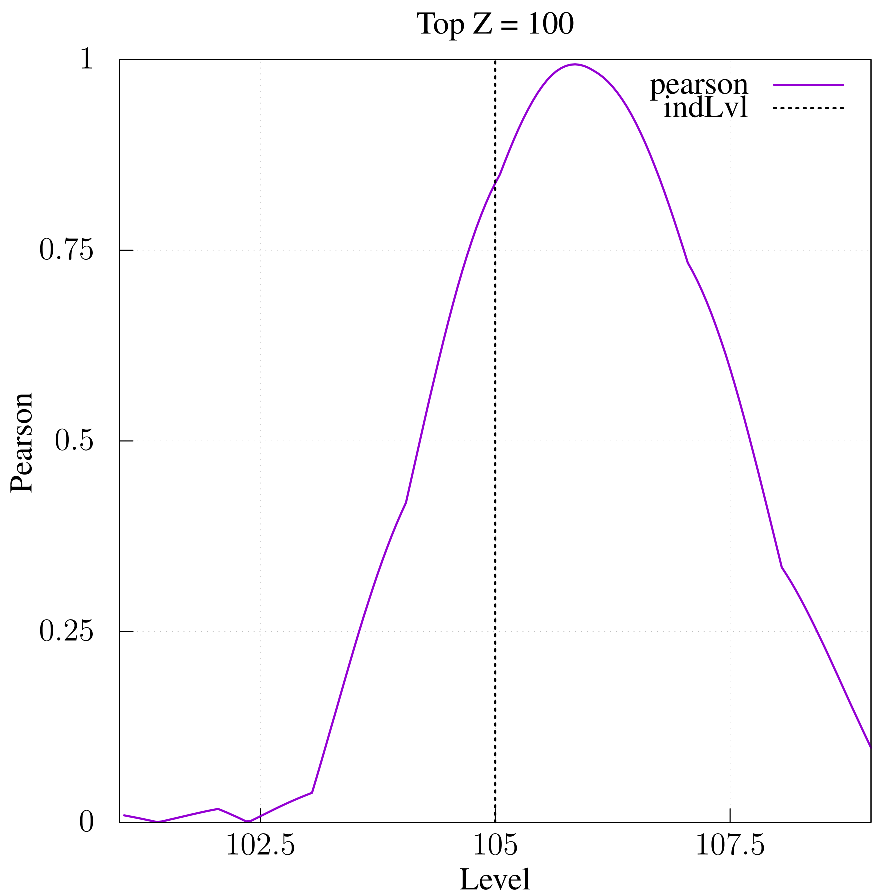


Figure 2: PCC obtained during Young's modulus determination for layers superimposition. The graph maximum shows the most likely layer shift after sample shrinkage under pressure.

For the sake of visibility, the subtraction process between particular layer from the first micro-CT and each layer from the particular region of the second micro-CT is presented in 2D form in Fig.3.

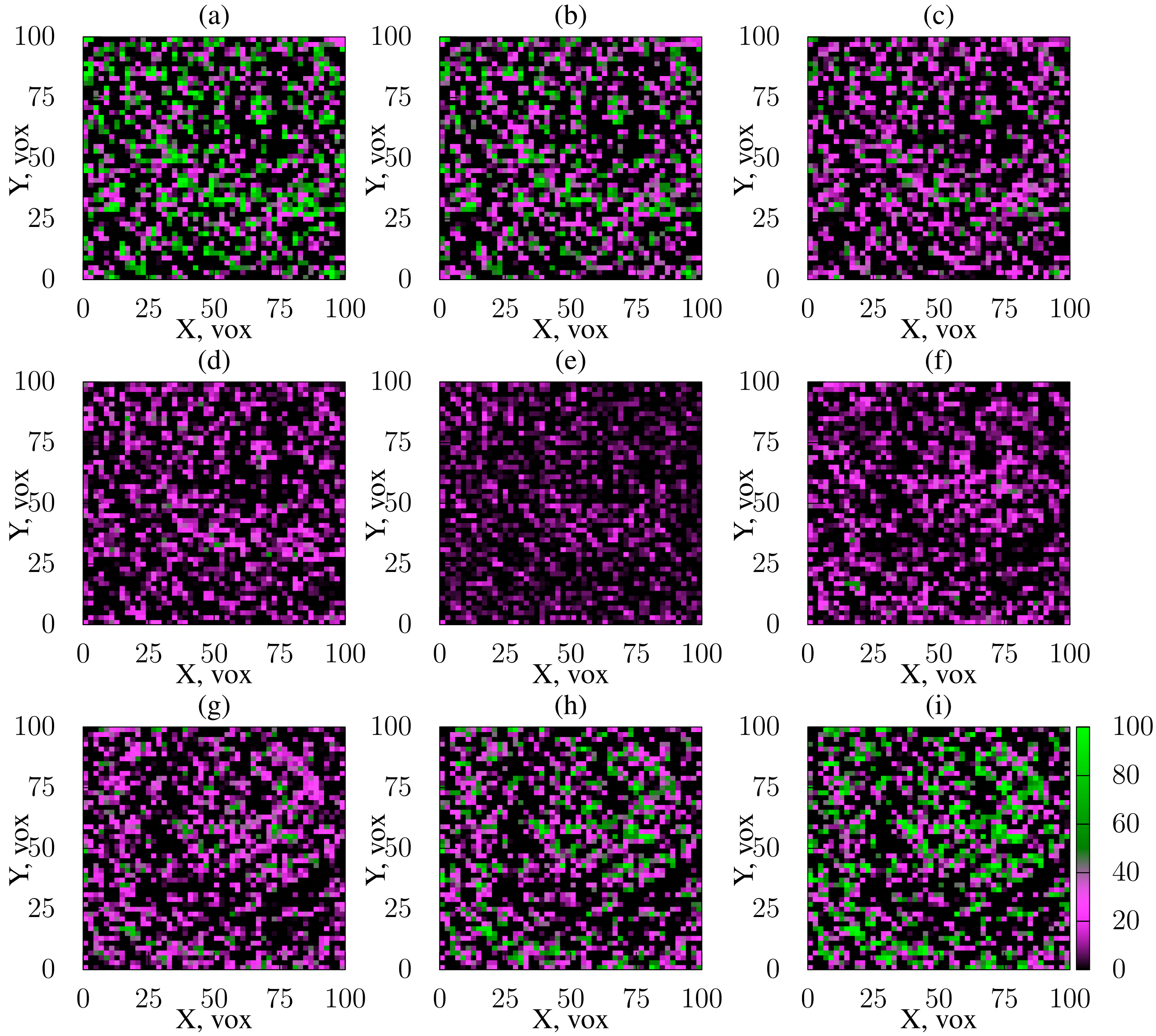


Figure 3: Young's modulus: visual 2D results of subtraction between the particular layer from the first micro-CT with the set of layers from the second micro-CT experiment. Voxels: a) 104; b) 104.5; c) 105; d) 105.5; e) 106; f) 106.5; g) 107; h) 107.5; i) 108.

Clearly, due to the coal heterogeneity, the Young's modulus may vary significantly in different core regions. Therefore, we identify Young's modulus in smaller core zones and calculate the average value afterwards (see Fig.4).

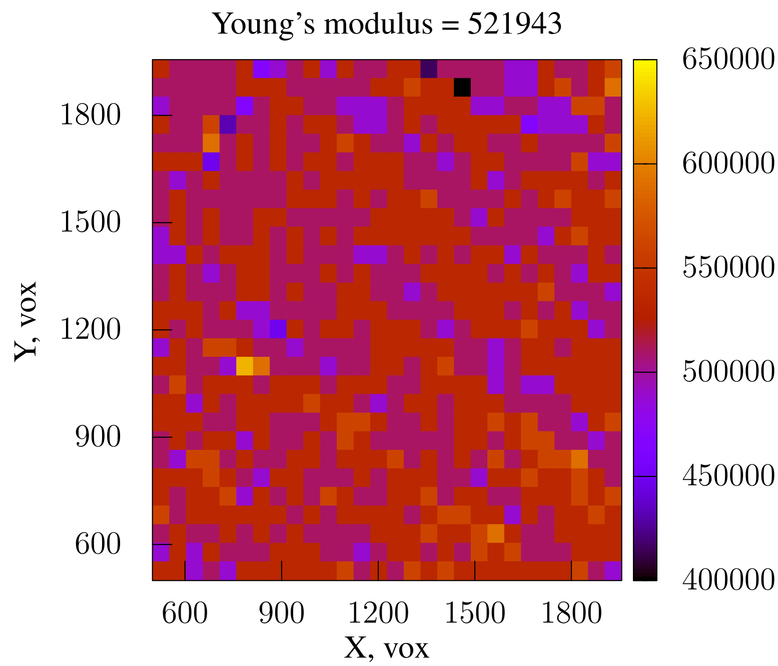


Figure 4: Young's modulus values in smaller sectors of the entire area of the sample. The overall value is found as an average.

As the same core may slightly change the position during two different experiments, their calibration relatively to each other is required. This calibration is performed by the spatial variation (using 6 degrees of freedom) of one micro-CT layer from the first experiment (e.g. $5,000\ psi$) in the particular zone of the second micro-CT image (e.g. $10,000\ psi$). For more details please refer to Fig.5 and Fig.6. The correct spatial variation is again found by analysing the PCC. The core region, where the comparison between two experiments is performed, is defined by the parallel translation from the calibration layer described above.

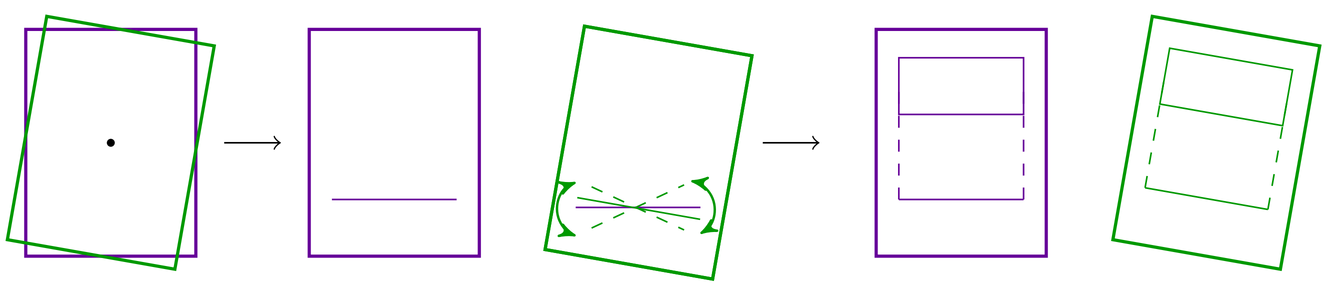


Figure 5: Schematic of calibration procedure

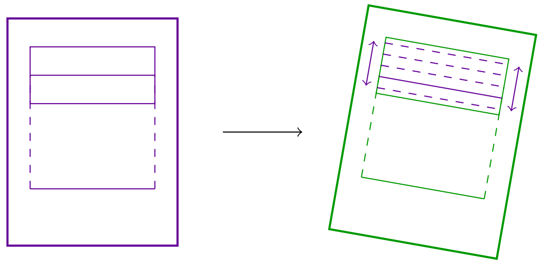


Figure 6: Micro-CT layers superimposition

3 Poisson's ratio determination

For Poisson's ratio determination the change in core length under different pressure conditions is also required. However, this data can be taken from the previous section when the Young's modulus was calculated. Knowing that from the calibrated samples, the radial enlargement is required for Poisson's ratio determination. The procedure is pretty the same as for the Young's modulus, but firstly a sample Cartesian grid is transformed into a cylindrical grid. Having this circumference, we then take two opposite sectors and identify the vertical layer shifts along the circumference radius.

In order to undertake the above procedure, the cylindrical grid should be artificially transformed into the Cartesian grid (see Fig.7).

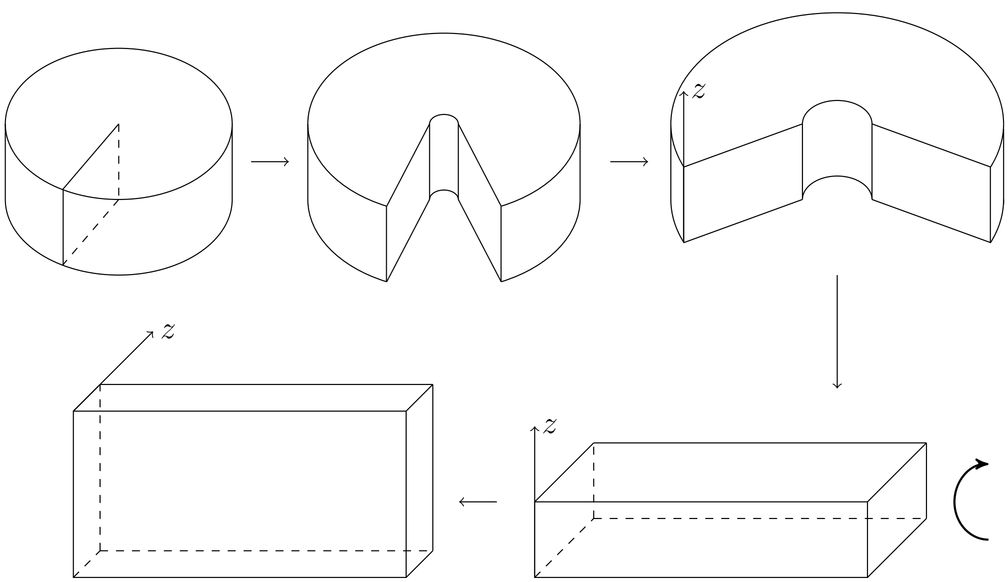


Figure 7: Grid transformation required for Poisson's ratio determination

As a results, the determination of radial enlargement becomes completely equivalent to the one utilized for the vertical elongation described above. Two following figures depict the PCC correlation showing the layer shift and 2D layer subtraction between two different micro-CT layers (see Fig.8 and Fig.9).

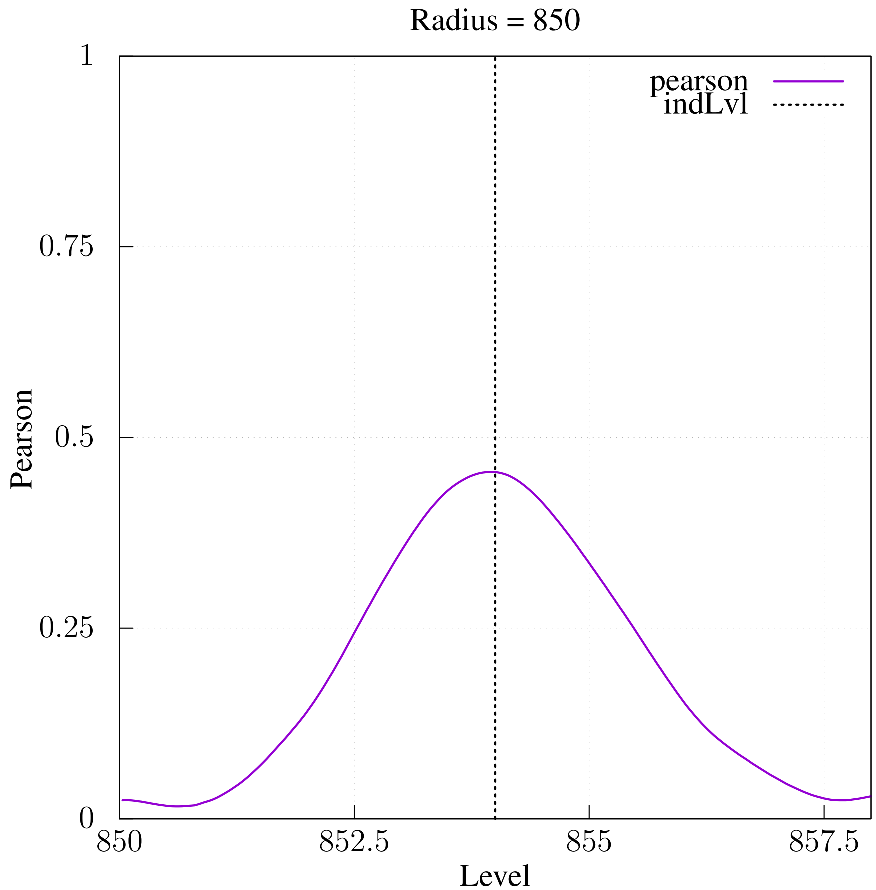


Figure 8: PCC obtained during Poisson's ratio determination for layers superimposition. The graph maximum shows the most likely layer shift after sample radial enlargement under pressure.

Thus, we find the core sample radial enlargement after its shrinkage under growing pressure. Knowing both the sample elongation and radial enlargement, the Poisson's ratio might be found. As coal heterogeneity leads to its uneven shrinkage, the Poisson's ration is identified along the whole circumference length from 0 to 180 degrees by taking small sectors and afterwards finding the average (see Fig.10).

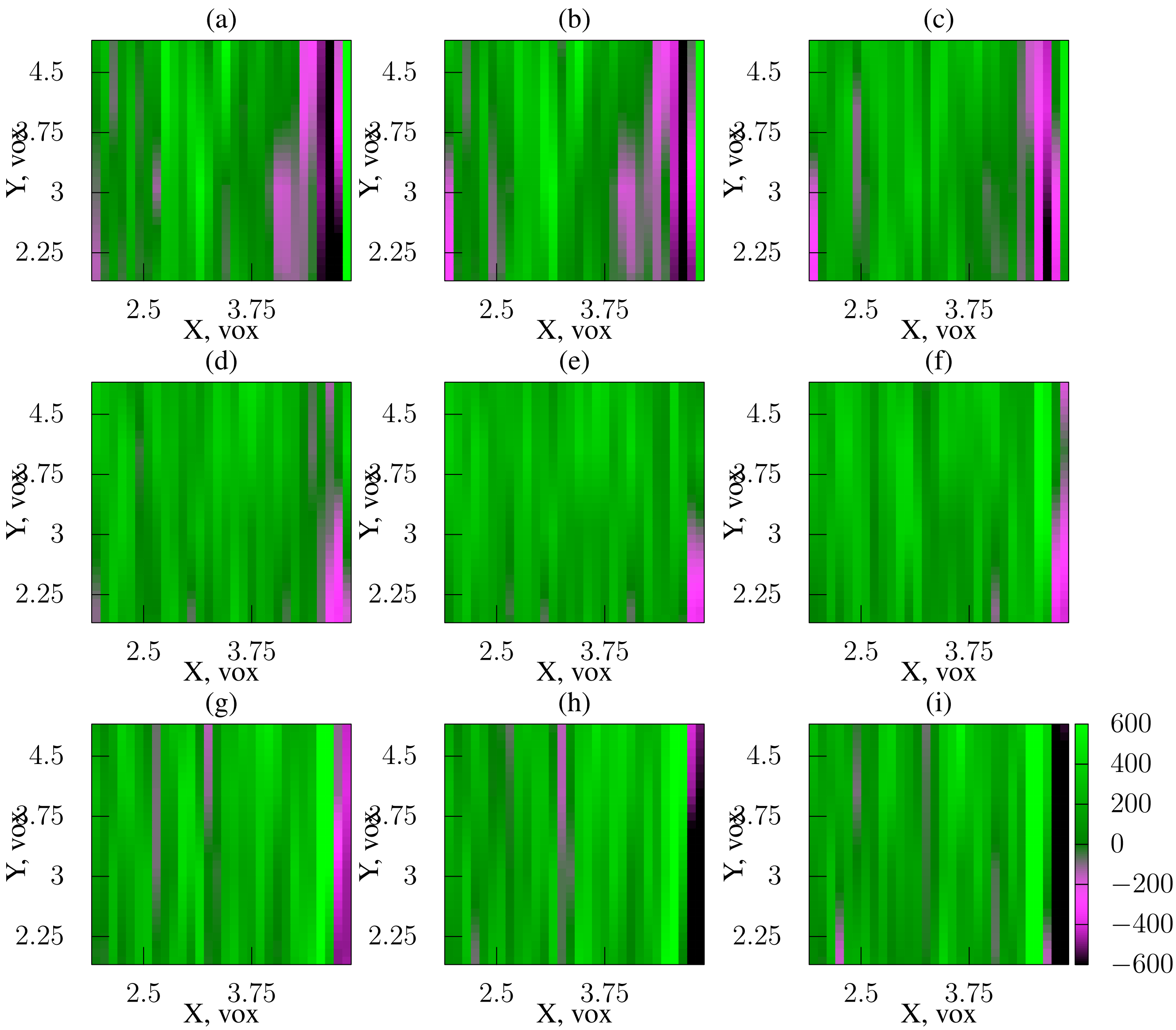


Figure 9: Poisson's ratio: visual 2D results of subtraction between the particular layer from the first micro-CT with the set of layers from the second micro-CT experiment. Voxels: a) 852.5; b) 852.8; c) 853.1; d) 853.4; e) 853.7; f) 854.0; g) 854.3; h) 854.6; i) 854.9.

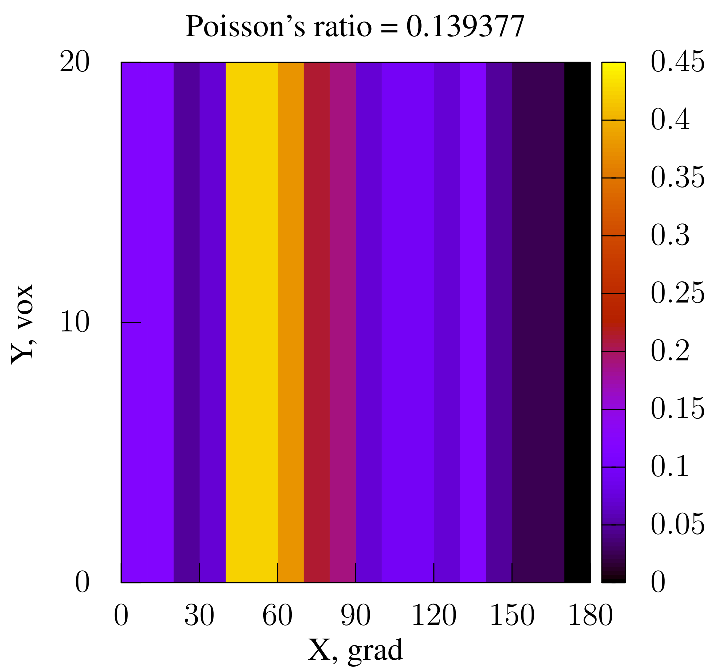


Figure 10: Poisson's ratio values in smaller sectors along the circumference (0 to 180 degrees). The overall value is found as an average.