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# Using Machine Learning to Automate Petrographic Analysis of Metallurgical Coke to Predict Reactivity

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## Introduction – Blast Furnaces, Metallurgical Coke and Petrography

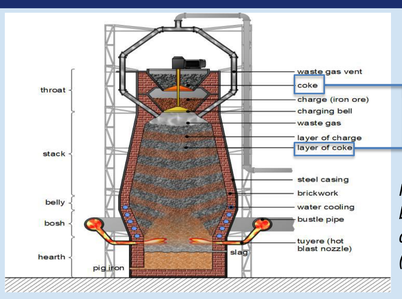



*Fig 1. Cross-section of basic blast furnace showing the alternating layers of burden (iron ore) and coke.*

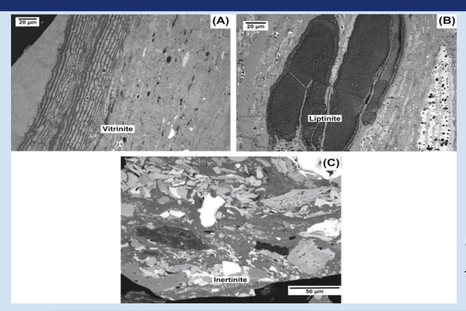



*Figure 2 . The three main maceral types found in coal.*

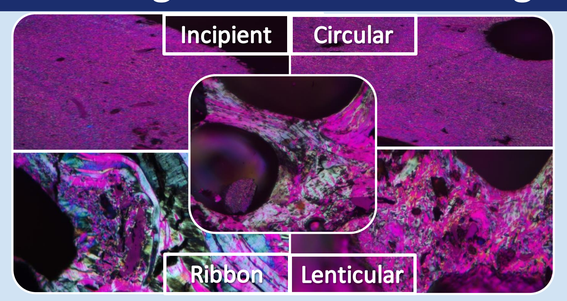



*Fig 3. Examples of the different morphologies found in Anisotropic coke.*

*Fig 4. Example of the type of optical microscope used in petrographic analysis*

- Metallurgical Coke is a carbonaceous material formed from the "destructive distillation" of coal.
- Made of a blend of bituminous coals that have specific properties.
- Coking coals have been identified as a critical raw material by the EU (European Commission, 2017).

- Petrography is the detailed study of coal and coke using optical microscopy.
- Thin sections of the coke are studied using polarised light.
- Allows the differentiation between different macerals in coal and morphologies in coke.

- Macerals in the coal predictively form known structures in the coke after carbonisation.
- This can be used to gauge the quality of the coals used in the coke-making process and the efficacy of the operation.
- Petrography can also be used to infer the performance of the coke in a blast furnace, which would otherwise involve expensive and time-intensive test work.

- Samples are prepared by crushing them, then mounting them in resin.
- The surface of the block is then polished block to reduce the risk of damage to the lenses of the microscope, whilst also helping to accentuate features within it.
- The block is then mounted onto a stand under the microscope and images taken of it in an oil immersion.

## The Theme of the Project

### The Problem

- Currently, petrographic analysis must be done manually
- It is conducted by an experienced chartered petrographer
- Analysis is done over 500 data points, and a manual tally is tabulated
- Relies on the expertise of the petrographer
- The information gleaned from petrography requires specialised knowledge to disseminate

### The Solution

- Automate petrographic analysis
- Translate the outputs to make it more accessible to blast furnace operators
- Correlate petrographic data to blast-furnace coke performance indicators

### Project Aims and Deliverables

- An automated petrographic image classification system
- The system must be able to compete with the manual procedure in accuracy and expediency
- A correlation between petrographic data and blast furnace coke performance indicators

## Methodology

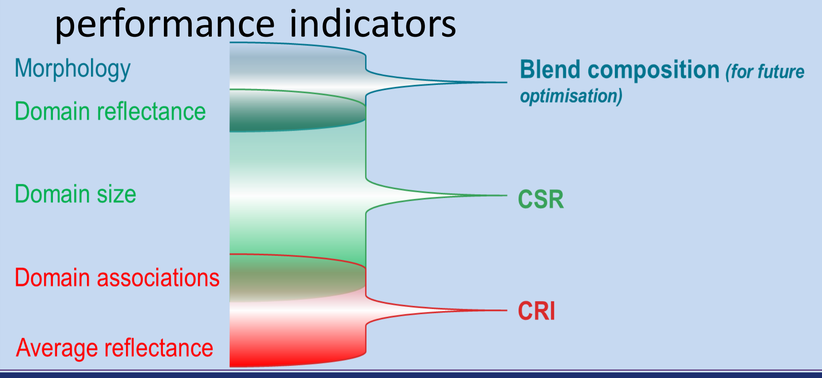
### Petrography Automation

- Using a Convolutional Neural Network (CNN) and advanced image processing tools, petrographic images of coke can be classified according to their morphology


*Fig 5. Typical output from a CNN, after classification*

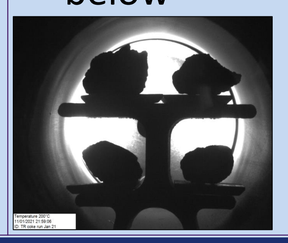
### Correlation to Blast Furnace coke KPI

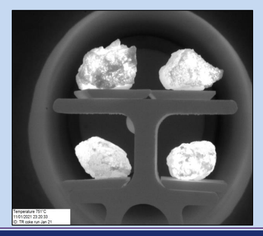
- Automated petrographic analysis can then be used to predict blast furnace coke performance indicators

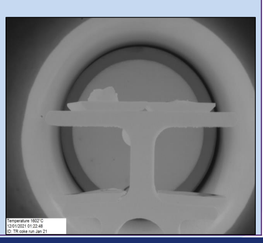



### Additional Work

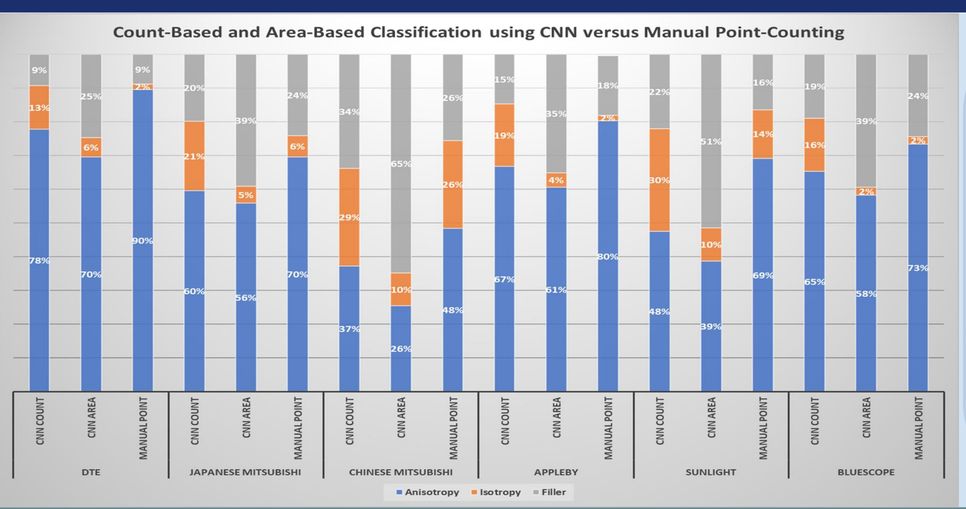
- An Ash Fusion Oven (AFO) fitted with a thermal camera can be used to track the temperature at which coke reacts, and the shape profile thereafter, as per the images below



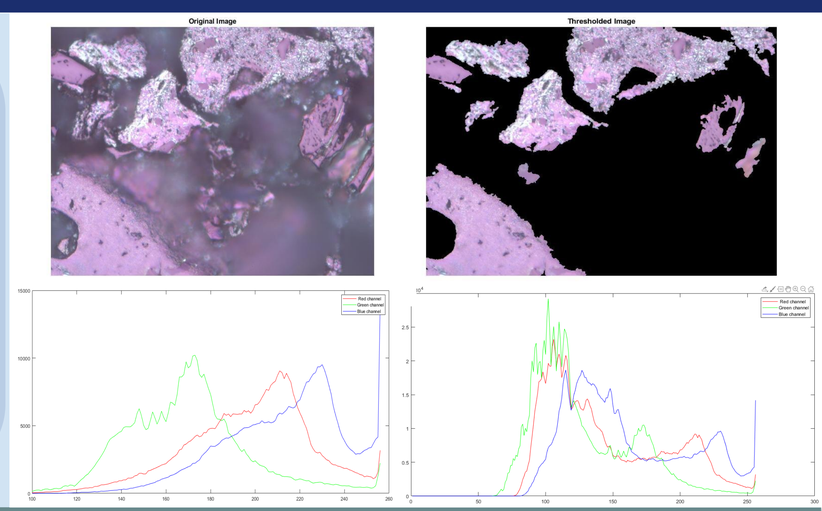




## Results and Further Work




- Results of the CNN's classifications are being compared to results obtained using the manual method.
- The high variability seen in the graph on the left can be reduced by improving the training data used by the CNN and by improving the accuracy of the image processing techniques used.
- By removing any parts of the image that don't contain any coke, the run-time of the CNN's classification programme can be greatly reduced, whilst simultaneously increasing its accuracy (Right).

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