Advanced Gas-Cooled Reactor Fuel Channel Bore Estimation Model

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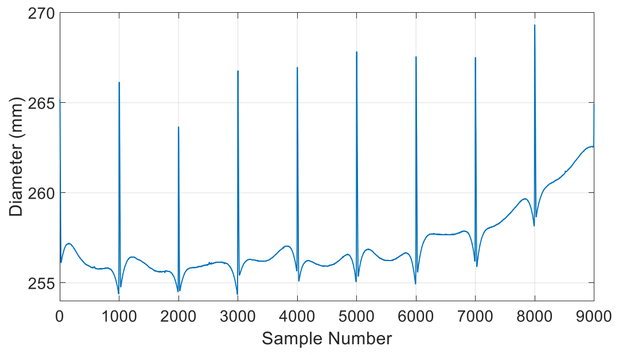
Introduction

- The main life-limiting factor of an Advanced Gas-Cooled Reactors (AGRs) is the graphite core, as it cannot be repaired or replaced.
- Installation of new monitoring equipment is difficult and expensive, therefore it is important to obtain the maximum amount of information from existing equipment.
- Currently, there are two main methods for obtaining information about the state of the core, either by visual inspection during scheduled outages or monitoring during refuelling events.

Inspection

- Inspection is performed by a Channel Bore Inspection Unit (CBIU) or a New In Core Inspection Equipment mark 2 (NICIE 2).
- Provides very detailed and direct offline information relating to the core.
- Undertaken during routine outages, typically every 12 months to 3 years depending on the age of the station.

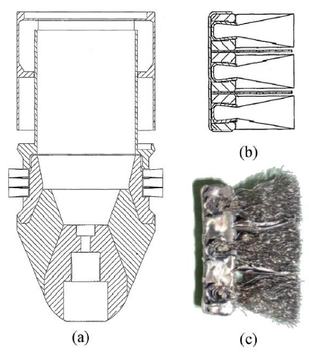
Channel Bore Inspection Unit diagram



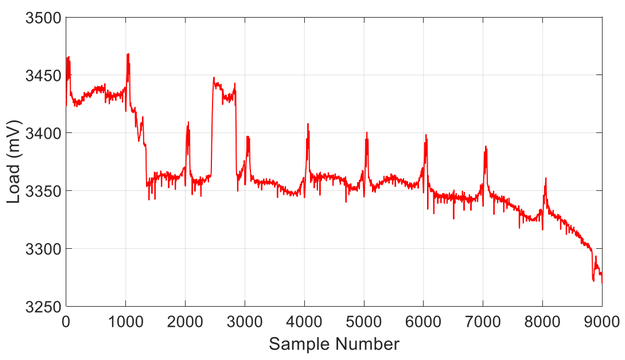
Example of CBIU data

Monitoring

- Monitoring data is obtained during refuelling events and gathered far more often than inspection data, is called a Fuel Grab Load Trace (FGLT).
- Provides less detailed information relating to the condition of the core.
- Measures the perceived weight of the fuel stringer as it is being removed (discharged) and inserted (charged).
- Lower stabilising brush (LSB) component of FGLT is proportional to the average bore of the fuel channel.



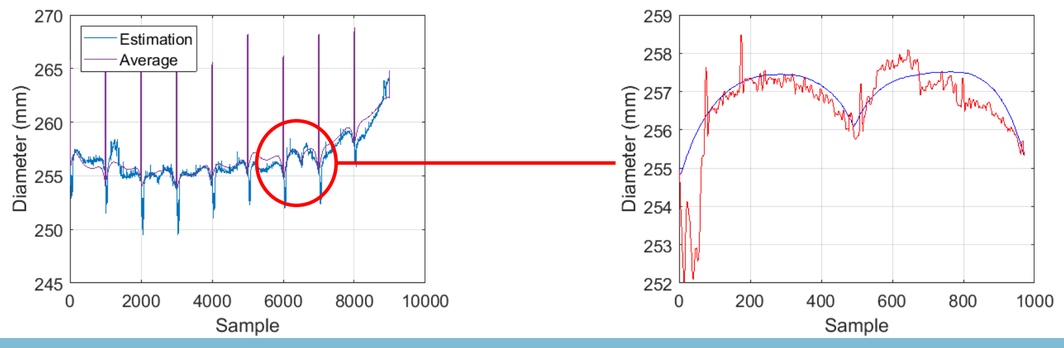
(a) Diagram of the nose assembly, (b) diagram of a cross-section of the lower stabilizing brush and (c) a photo of a cross-section of the lower stabilizing brush.



Example of FGLT data

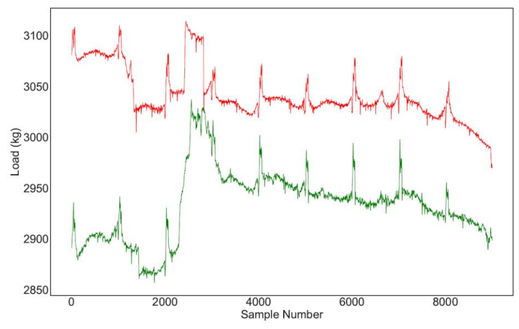
Offload Bore Estimation

- As there is a much more abundant supply of monitoring data compared with inspection data, a model has been trained to produce comparable measurements to that produced by the inspection data.
- Using the current bore estimation model, for most of the datasets tested, it is possible to convert low detailed monitoring data to produce results that closely match the higher detailed inspection data.
- This can also be used to highlight cracks in individual brick layers with similar accuracy to the more infrequent inspection data.

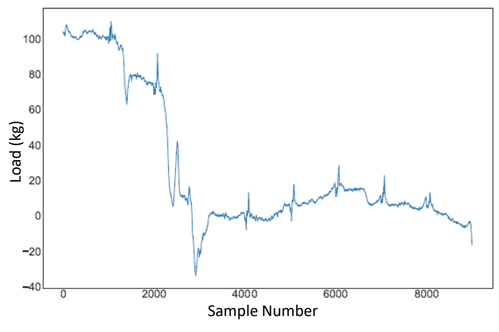


Onload Bore Estimation

- Data gathered during onload refuelling has the added complication of the interaction between the fuel assembly and coolant gas.
- This effect cannot be directly measured, so initially, an empirical model was created by comparing onload and offload data.

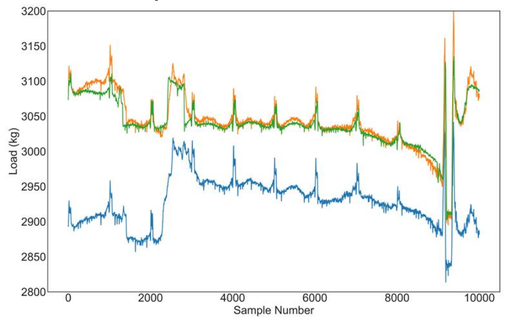


(Red) Offload FGLT and (Green) Onload FGLT

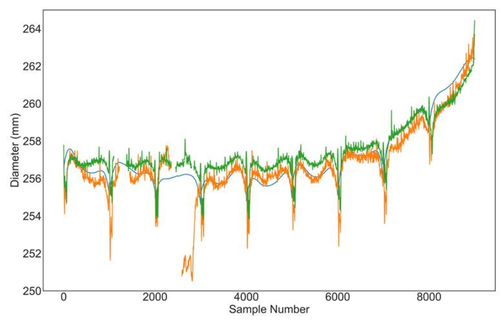


Empirical gas flow model

- This model is then used to estimate the offload equivalent FGLT response, then by using the bore estimation model, trained on offload data, it is possible to produce bore estimations for onload FGLT data.



(Green) Offload FGLT, (Blue) Onload FGLT, and (Orange) Equivalent Offload FGLT



(Blue) CBIU data, (Green) Bore estimation from offload data, (Orange) Bore estimation from onload data

Deployment

- Lumen is an online platform that has real-time access to the most up to date database of monitoring and inspection data.
- Having fully developed and tested the algorithms, they are deployed in Lumen to be used by EDF Engineers to assist their analysis of the health of the graphite core of the UK's Advanced Gas-cooled Reactors.

Example of bore estimation algorithm deployed in Lumen. Not representative of real data

Conclusions and Future Work

- Currently, the bore estimation model uses a linear regression model to convert load to channel bore diameter, through physical understanding this is obviously not the case, in the future, a non-linear approach will be developed.
- Using the gas flow removal algorithm it has been successful to produce accurate bore estimation from onload data gathered within the last 12 months.
- Using the gas removal algorithm and bore estimation model comparisons will be done between bore estimations from onload and offload data with inspection data to better understand the evolution of cracks.

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