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Assessing Coal Properties and Their Effects on Coking Performance: A Data Mining Approach

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Abstract

Within the cokemaking industry, the ability to accurately predict the quality of coke produced from a variety of global coal basins is limited. Since the most recent review of coke quality prediction models, completed by Díez et al. (2002) on a selection of key models within the literature, very little improvement in prediction ability has been shown. In particular, the existing coke quality prediction models are deficient in their ability to link and expand upon reported fundamental coal behaviour. Where emerging data mining techniques have been applied for model development, often a clearly defined and technically sound analytical process has not been described. In this context, data mining as one step in the knowledge discovery process, has presented a unique opportunity to provide further insight into the behaviour of coking coals, and in particular, allowed for integration and extension of fundamental coking behaviour.

Research Outcomes

Based on the conclusions of an extensive literature review considering both coking behaviour, and analysis of the methods of prediction of coke quality, a sub-model approach to prediction was developed. This sub-model approach addresses the some of the fundamental processes occurring within the formation of coke from the parent coals, whilst integrating data mining techniques. The following knowledge gaps were explored, with clearly defined frameworks for prediction developed:

Vitrinite reflectance distribution classification using self organising maps

Vitrinite reflectance is perceived as an important parameter in coke quality, however in coal blending, utilising the average value is unsuitable as it does not reflect how two coals of vastly different reflectance have been blended.

Classification of the resulting distributions allows further insight into these blending decisions.

Prediction of coal fusibility using a Sugeno fuzzy inference system

Traditional prediction models consider fusibility of coal sub-components as one of the main factors in determining coke quality. However, the assumed proportion of fusing and non-fusing components is unreliable for Australian and other coals. Hence, accurate prediction of these fusing components for each respective coal ought to improve prediction of coke quality. Data quality issues associated with the comparatively small and biased data set were also explored. This section discusses how some of these issues can be addressed by using a modified data oversampling technique based on the Synthetic Minority Oversampling Technique (SMOTE).

Approximation of coal mineral composition from coal ash chemistry using a genetic algorithm

Coal ash chemistry is commonly used in the prediction of coke reactivity. However, the use of ash chemistry may be misleading as it does not directly reflect the mineral forms present in the coal which may have different influences on reactivity.

Inference of coal mineral behaviour on coke reactivity using a support vector machine

Whilst basicity index, derived from coal ash chemistry, is often applied in coke quality predictions, questions are raised over the relative importance of different minerals on coke reactivity, and whether the index is misleading. Using the approximated coal mineral composition, an improved understanding of coal reactivity behaviour is developed.

Final prediction and assessment of individual sub-models on coke quality using a support vector regression

Results show statistically significant improvement in predictive accuracy with the use of the vitrinite reflectance distribution terms, as well as the use of coal mineral composition.

The development and integration of these models in a clearly defined predictive framework presents a significant improvement to many traditional predictive models. Further, consistency with experimental studies was observed, with several areas for future work identified. This work has significant implications on not only the methods of prediction of coke quality, but also on the confirmation and integration of experimental findings.

Certificate of Originality

I hereby certify that the work embodied in this thesis is my own work, conducted under normal supervision.

The thesis contains published scholarly work of which I am a co-author. For each such work a written statement, endorsed by the other authors, attesting to my contribution to the joint work has been included.

The thesis contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

I give consent to the final version of my thesis being made available worldwide when deposited in the University's Digital Repository, subject to the provisions of the Copyright Act 1968, and any approved embargo.

Lauren North – PhD Candidate

Signature ________________ Date 19th May 2020

Acknowledgement of Authorship

I hereby certify that the work embodied in this thesis contains published paper/s/scholarly work of which I am a joint author. I have included as part of the thesis a written declaration endorsed in writing by my supervisor, attesting to my contribution to the joint publication/s/scholarly work.

By signing below I confirm that Lauren North contributed the primary intellectual input to the creation of and all analysis contained in the following papers and publications:

North LA, Blackmore KL, Nesbitt KV, Hockings K, Mahoney MR (2019) Understanding the impact of coal blending decisions on the prediction of coke quality: a data mining approach. International Journal of Coal Science & Technology 2:207-217 doi https://doi.org/10.1007/s40789-018-0217-2

North L, Blackmore K, Nesbitt K, Hockings K, Mahoney M (2018) Exploration of Coal Fusibility in the Cokemaking Process and the Links to Coke Quality. Paper presented at the 8th International Congress on Science and Technology of Ironmaking - ICSTI 2018, Vienna, Austria

North L, Blackmore K, Nesbitt K, Mahoney M (2018) Models of coke quality prediction and the relationships to input variables: A review Fuel 219:446-466 doi:https://doi.org/10.1016/j.fuel.2018.01.062

North L, Blackmore K, Nesbitt K, Mahoney M (2018) Methods of coke quality prediction: A review Fuel 219:426-445 doi:https://doi.org/10.1016/j.fuel.2018.01.090

North L, Blackmore K, Nesbitt K, Hockings K, Mahoney M (2017) A Novel Approach to Coke Strength Prediction Using Self Organizing Maps. Paper presented at the DMIN'17 - The 13th International Conference on Data Mining, Las Vegas, USA

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List of Publications

Parts of this thesis have been published in the following works:

North LA, Blackmore KL, Nesbitt KV, Hockings K, Mahoney MR (2019) Understanding the impact of coal blending decisions on the prediction of coke quality: a data mining approach. International Journal of Coal Science & Technology 2:207-217 doi https://doi.org/10.1007/s40789-018-0217-2

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