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Modeling and Optimization of Carbon Dioxide Capturing using Cement Kiln Dust by Mineral Carbonation: Comparison between Response Surface Methodology and Artificial Neutral Network

Abstract

The use of computer software in the field of engineering is very useful and efficient, such examples of software are Response Surface Methodology (RSM) and Artificial Neural Networks (ANN), these two software were used to model and optimize the process of carbon dioxide capturing using Cement Kiln Dust (CKD) by mineral carbonation. Carbon dioxide capture and storage (CCS) is a possible option of lowering CO_2 emissions, which contribute to global warming.

Objective and Motivation

CCS (carbon dioxide capture and storage) is a viable approach for reducing CO_2 emissions, which contribute to global warming. Mineral carbonation, Comprehensive literature study of CCS technology, specifically mineral carbonation, investigating the impact of various factors on CO_2 sequestration and their interactions. A comparative study of RSM and ANN modeling to predict CO_2 sequestration using Cement Kiln Dust for mineral carbonation. This technology has not yet been completely developed, particularly for use in power plants there is a need to create a practical and effective method for speeding up the carbonation reaction so that CO_2 may be trapped and sequestered at the same rate as it is produced by fossil fuel burning in power plants.

Design and Implementation

The main objective of the projects which includes the design of the experiment (RSM), ANN training (MATLAB), and finally, statistical analysis approaches to validate the result is designed. RSM can be used to optimize operational parameters in order to maximize the production of a certain material as well as MATLAB to design the ANN model and its is a machine learning model at the heart of deep learning algorithms inspired by the network of biological neurons found in the human brain. ANN is a data-Centric approach.

Minitab v14.0 is used to calculate the second-order polynomial coefficients, perform analysis of variance (ANOVA), and regression analysis on the produced designs with the data. BBD was analyzed for calcium leaching using four separate parameters, and for the carbonation, CCD with two factors. The Neural Network Toolbox included in MATLAB tools for creating, implementing, and debugging neural networks is used to build and optimize the model.

Results

Four main parameters (temperature, CKD sample dose, time, and acid concentration) for calcium leaching yield have been optimized in case of the RSM model an ideal set of 4.09 M acid concentration, 90 °C leaching temperature, 27 min leaching time, and 13.8 g of CKD sample, the maximal calcium yield was found to be 98.58 %, and in the case of the ANN model an ideal set of 3.8848 M acid concentration, 90 °C leaching temperature, 5 min leaching time, and 12.3664 g of CKD sample, the maximum calcium yield was found to be 100 %. The RSM model gave good results with R2 93.6% whereas the ANN model of one hidden layer and 13 neurons fit with R2 99% and was generally more accurate. For carbonation efficiency, two parameters (CO2 flow rate and temperature) were optimized, the RSM model resulted in an ideal set of 1520 cm3/min CO2 flow rate and reaction temperature of 90 °C, the maximum carbonation efficiency was found to be 82.76 % and the ANN model of one hidden layer and 18 neurons resulted in optimized set of 1222.21 cm3/min CO2 flow rate and 86.82 °C reaction temperature with a maximum carbonation efficiency of 89.52%. The RSM model gave acceptable results with R2 69.35% whereas the ANN model gave R2 99% and was significantly more accurate.

Conclusion

This project demonstrates the ability to optimize an engineering problem using software-aided models, comparing between Response Surface Methodology and Artificial Neutral Network for carbon dioxide capturing using Cement Kiln Dust by mineral carbonation. Mineral carbonation has some potential advantages over other available CCS technologies. ANN model is a better empirical modeling technique.

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