Adaptive soft sensor to predict alite fraction clinker production through quasi-ensemble PLS modelling

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Alite is a form of tricalcium silicate that is the essential constituent of Portland cement clinkers. In cement industry, the alite fraction can be determined only through off-line laboratory measurements collected at a low frequency. However, due to digitalization, cement production plants are heavily instrumented and collect dozens, if not hundreds, of online process variables, e.g. kiln temperature, torque, etc., at a high frequency, retaining the fingerprint of the product quality in terms of alite fraction (Lea et al., 2019). For this reason, adaptive soft sensors (Souza et al., 2016) can be utilized to exploit the wealth of information of the on-line collected data and estimate in real time the alite fraction. The model is developed based on data taken from an industrial case study which is characterised by the following challenges: highly correlated variables, nonlinear and dynamic behaviour, typically due to seasonal effects or drifts for equipment aging and/or fouling. Thus, a latent-variable regression method, e.g. Partial Least Squares PLS, (Geladi and Kowalski, 1986), is used to estimate the alite fraction from online process measurements, while adaptive modelling (Joe Qin, 1998) is adopted to update the soft sensor to the changing features of the plant. Finally, local models are used to tailor the model adaptively on the characteristics of the most similar observations in the historical data to deal with nonlinearities. However, maximizing the accuracy of the soft sensor requires tuning several hyperparameters (i.e., the number of latent variables of the PLS models and the number of observations to build local models), whose optimal values identification is not trivial. Hence, in this work we propose a technique inspired by ensemble modelling, but instead of using different training dataset partitions to construct the sub-models (Cao et al., 2017), we build the ensemble using different sets of values of the above-mentioned hyperparameters. Then, the estimations of the sub-models are averaged to obtain the final ensemble prediction of alite fraction, while variability identifies the estimation uncertainty. The soft sensor is tested on an industrial case study of clinker production and shows very promising results. In particular, the adaptive soft sensor demonstrates to be accurate and precise, correctly capturing the trend of the alite fraction.

Keywords: adaptive modelling, cement industry, ensemble modelling, PLS, soft sensing.

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