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Multimode process monitoring based on data-driven method

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Abstract

In this paper, a new data-driven method and its application to process monitoring is proposed for handling the multimode process monitoring problem in the electro fused magnesia furnace (EFMF). Compared to conventional methods, the contributions are as follows: (1) New similarity between different mode is defined with weighted norm distance which can extract common and special feature of all modes respectively, and the similar degree is analyzed; (2) Multi-mode modeling method is then proposed based on the similarity defined above; (3) Fault caused by different section often performs abnormal in different subspace, so we applied the fault detecting indices with the multi-mode model. The experiment results show the effectiveness of the proposed method.

1. Introduction

In consideration of ensuring the safety of equipments and the quality of products, monitoring of process performance has become an indispensable issue. In order to enforce the rationality and effectiveness of monitoring, in the last few decades, multivariate statistical process monitoring (MSPM) has been intensively researched. Particularly, principal component analysis (PCA) and partial least squares (PLS) which are widely applied in the industrial process have been important approaches for monitoring of the process performance [1,4,5,18], and some improved methods,

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such as kernel principal component analysis (KPCA) and kernel partial least squares (KPLS) have achieved great success in process monitoring and fault diagnosis [2,3,14,34]. Multi-way based method has also been proposed to deal with batch processes [6–8].

Recently, monitoring for multimode processes is an urgent mission for various reasons, such as in safety control, waste-stream reduction, consistency and quality improvement. In the industrial process, the same production line is often used to produce different products. Therefore, there are often different production modes in the same production line, which makes dynamical multimode batch process more complicated [9,10,13] and there exists data need to be analyzed. Recently, some research effort has been reported to solve the multimode process monitoring problem through some modified PCA/PLS methods. Zhao et al. [32] developed multiple PCA/PLS models for multimode process monitoring.In the preliminary step, however, a priori process knowledge is required to manually segment the historical operating data into multiple groups that correspond to different operating modes which is unconvinent. Moreover, a similarity threshold has to be predefined by user to incorporate the similar data groups. Those conditions are not desirable for automatic process monitoring in industrial practice. For example, the most intuitive remedy is to develop separate model corresponding to specific operating mode. However, since these operating modes are usually not well-defined whilst difficult to identify, it is critical to assess the similarities or equivalently, the differences for any two models. Otherwise, more and more models will unavoidably be constructed as the process proceeds [33].

Considering that the mode multiplicity is an inherent nature of multimode process, various strategies have been reported and can be applied into process monitoring [19]. One is to build the variable correlation model within each mode under the influence of other modes by multi-block partial least squares (MBPLS). Compared with MPLS, the advantage of MBPLS is mainly the easier modeling, and it considers both the roles of each smaller meaningful block and the integrated contribution of all blocks [16]. Further, Reinikainen and Hoskuldsson reported a priority PLS regression analysis method and its successful application to a multi-step industrial process, which gave multimode descending priority following operation time sequence. The idea was to compute the model information only on the basis of first mode. When no more significant latent vectors could be found from the first mode, the next model information was extracted from the data of the second mode so that the left process information that was not modeled by the previous mode would be explained by the following modes. Yu and Chiang presented a multi-modes statistical analysis method to reduce the complexity of fast process analysis [20,21]. It revealed that which part variation within each mode was responsible for process variations and which part was dominated [12,17,22]. For process monitoring, the subPLS modeling algorithm was developed where the regression model was suitable for all measurements within the same mode. It was based on such a presupposition that despite the time-varying mode operation trajectory, the correlations between process and process variables should remain similar within the same mode. Further researches have also been developed [23–25]. Ge and Song [26] proposed a multimode process monitoring approach based on the Bayesian method. By transferring the traditional monitoring statistic to fault probability in each operation mode, monitoring results in different operation modes can be easily combined by the Bayesian inference. This approach requires modeling for all the modes.

In our earlier work, the common score algorithm across data includes two versions, common score and common weight, which extract the similar scores and weights respectively. Actually, the algorithm is directly related with the common eigenvectors which will make the same contribution to processes [27–29]. However, the common information part cannot be obtained. In this work, a between-mode process modeling approach is proposed for transition analysis and

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