CHAPTER 3

LITERATURE REVIEW

3.1. Introduction

The demand of manufacturing processes are raising rapidly, with higher target levels of quality, throughput, and yield, at the same time as lower cost, less waste, and less pollution are desired. The improvement of processes to meet these demands necessitates better knowledge about the processes and the processes operations, as well as better control of process conditions such as temperatures, flows, pressures, and concentrations. This, in turn, demands more abundant, better and more frequent measurements in all parts of the processes, including raw materials, intermediate, catalysts, etc.

The results of frequent process measurements with multiple instruments and sensor arrays are, however, a rapidly increasing volume of process data that needs appropriate analysis. To use and display the information in these data projection methods such as principal components analysis (PCA), projection to latent structures (PLS) and their generalizations works very well. These methods deal with multitudes of collinear, noisy, and incomplete data, and give easily interpretable results such as scores, deviations from the method, and variable contributions.

3.2. Literature Review

Neal B. Gallagher and Barry M.Wise [1997] were developed multivariate statistical process tools for monitoring and fault detection on a Lam 9600 Metal Etcher. Application of these methods is complicated because the process data exhibits large amounts of normal variation that is continuous on some time scales and discontinuous on the others. Variations due to faults can be minor in comparison. Several methods based on *principal component analysis* and variants that incorporate methods for model updating have been tested for long term robustness and sensitivity to know faults. Model performance was assessed with about six month's worth of process data and a set of benchmark fault detection problems.

This study has shown how one can systematically step through the options for sensor systems and data treatment for fault detection systems in order to select the best measurements and analysis method for the particular job. For this particular application, simpler methods, such as PCA on the means, tended to work best. The major unresolved issue in this article concerns dealing with process and sensor drift. It is apparent that this had a major impact in this study. This issue is the subject of the companion article.

Jong Ku Lee and Chonghun Han [1999] used Multivariate statistical methods to monitor and diagnose the operation of a batch PVC process by using *multiway PCA*. The system allowed us to monitor the polymerization process and detect most suspicious fault on-line. Furthermore, the system informs operators of the physical properties of PVC such as porosity and particle size distribution on-line.

The process monitoring systems have been developed based on multivariate statistical techniques and successfully implemented to industrial polymerization processes. Since these monitoring systems offers simple and compact SPC charts, they enable operators to detect the fault at their early stage on-line and help identify suspicious causes. Through the effort to find out the correlation between process variables with principal component analysis, the improved process knowledge has been gained and this knowledge has led to the better control of processes. The ultimate goal is to minimize process and quality variation and to provide customers with an enhanced product consistency.

Paul Nomikos and John F. Macgregor [1994] used *multiway principal component analysis* to extract the information in the multivariate trajectory data by projecting them onto low-dimensional spaces defined by the latent variables or principal components.

These leads to simple monitoring chart, consistent with the philosophy of statistical process control, which capable of tracking the progress of new batch runs and detecting the occurrence of observable upsets. The approach is contrasted with other approaches, which use theoretical of knowledge-based model, its potential is illustrated using a detailed simulation study of a semibatch reactor for the production of styrene-butadiene latex.

The approach based on the basic concepts of Statistical Process Control (SPC), whereby the future behavior of a process is monitored by comparing it against that observed in the past when the process was performing well, that is in a state of statistical control. Control limits for the monitoring charts are derived from statistical properties distribution of past "good" batches. Therefore, the approach relies upon the idea that future "good" batches should have similar behavior to past one. The proposed monitoring charts that can be easily displayed, interpreted, and can quickly detect a fault.

J, Edward Jackson [1980] presented Principal Component technique, which use to compare between two different methods of quality control test in a chemical process. Normally, method A was fairly easy to carry out but which occasionally experienced equipment failure, method B was a more difficult test but was more reliable. He introduced the basic of Principal Component such a matrix algebra, covariance matrix, application of the method to statistical analysis, how to apply Principal Component for quality control etc.

Lee, D.S., and Vanrollegham, P.A. [2003] proposed new monitoring algorithm, adaptive multiblock multiway principal component analysis (MPCA). The method overcomes the problem of changing process conditions by updating the covariance structure recursively. A historical set of operational data of a multiphase batch process was divided into local blocks in such a way that the variables from one phase of a batch run could be blocked in the corresponding blocks. This approach has significant benefits because the latent variable structure can change for each phase during the batch operation. The adaptive multiblock model also allows for easier fault detection and isolation by looking at the relationship between blocks and at smaller meaningful block models, and it therefore helps in the diagnosis of the disturbance. The proposed adaptive multiblock monitoring method is successfully applied to a sequencing batch reactor for biological wastewater treatment.

Seongkhu Yoon and William Pepe [2003] presented process control monitoring with multivariate process monitoring and early fault detection (MSPC) by using PCA and PLS. The objectives of the project were to build the furnace monitoring models and the prediction models of the natural gas flow rates. Principal Component (PC) models for the furnace monitoring and PLS models for the prediction of the natural gas flow have been built and assessed to achieve the objectives. Before building the multivariate correlation models, the data were audited and preprocessed. Since the caking information was not provided, the caking datasets were carefully screened from the original data. In additional, the training data were prepared by removing outlier and unreasonable observations.

Since the effects of the process dynamics were significant, the key variables were lagged for modeling. For parsimoniousness of the correlation models, ARX was used. Based on the PC models, all the caking in the test datasets were detected a few hours in advance such that operational staff would be able to make corrective actions. Now operation staffs are easily able to detect the furnace caking with both DModX and Hotelling's T^2 statistics as an contribution plots. Thus, one can successfully monitor furnace caking as well as any type of abnormal event.