Abstract

To remain competitive in global marketplace, it is extremely challenging to suffice the stringent quality requirements in terms of designing process parameters and tolerances, diagnosing the abnormalities in the process elements and inferring about the process degradation before it fails posing as a hindrance in achievement of desired quality of final products. Recent advancements in online sensing technologies and sensor data storage have provided the quality professionals a great opportunity to analyze the sensor data in describing and inferring about the underlying process for quality improvement. The objective of this research is to offer guidelines for data driven process oriented quality improvement in multistage manufacturing processes especially when the system is an under-determined one in particular, by selecting the optimal process parameters and process tolerances, correctly identifying the faulty process elements to meet quality requirements and finding the remaining useful life of the process elements when the system is continuously degrading over time.

The first objective has been addressed to designing a methodology for integrated parameter and tolerance design of process elements in an under-determined process scenario utilizing computer experiment based surrogate modeling of the quality conformance index which is motivated by Taguchi's Quality Loss concept. Conventionally, parameter and tolerance design are executed in sequential manner which is reportedly sub-optimal in nature. In this objective, an integrated method is proposed to design the process parameters and process tolerances simultaneously.

As in the under-determined systems, estimation of significant predictor variables lead to the situation of no-unique solutions. So, the conventional least-squares based methods fail to capture those significant predictor variables. In second objective, a penalized regression approach based on Bayesian hierarchical modeling strategy has been adopted to identify the most significantly contributing process error sources to the abnormality in the manufacturing process under consideration. Variational Bayesian inference technique which is a deterministic simulation method as contrary to the Metropolis-Hastings approaches, has been sorted out to estimate the out of specification process variance sources, that are the faulty elements in the process.

In third and last objective, a generic methodology has been developed aiming at prognosis of failure of process elements in under-determined multistage manufacturing process. Firstly an online filtering based approach has been developed for estimating the state of the process elements at any time instant when the under-determinedness is the prime issue in uniquely estimating the same. Then based on the stochastic degradation models, the remaining useful life of the process components are estimated.

The primary contributions of this thesis are (i) developed a generic model for multioutput Non-parametric Regression model for partially diagnosable system which is conceptualized on Gaussian Process based model and implemented the same to model the computer experiment data for joint parameter and tolerance design task in case of multistage manufacturing process, (ii) developed a Bayesian hierarchical regularized model for diagnosing the faulty process elements in a multistage manufacturing process with partial diagnosability and (iii) developed a methodology for determining the remaining useful life distribution of process elements utilizing the product quality data. Moreover, these developed models are extensively tested and validated on some simulated datasets from a real partially diagnosable multistage manufacturing process.

Keywords: Multistage Manufacturing Process, Quality Improvement, Partial Diagnosability, Compressive Sensing, Sparse Systems, Bayesian Hierarchical Modeling, LASSO, Variational Inference, Parameter and Tolerance Design, Gaussian Processes, Fault Diagnosis, Remaining Useful Life, Sparse Dynamic Model