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Robust Parameter Control Based on Selecting Online Controllable Variables

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Abstract

Robust parameter design (RPD) is considered as a cost effective tool for reducing process variability. Robust parameter control, integrating RPD with automatic process control, will performance better than the traditional RPD approach. This paper proposed a strategy of robust process control based on selecting online controllable variables with consideration of generalized quality cost, which includes quality loss and manufacturing cost. Firstly, online controllable variables were selected and offline controllable variables were optimized in the design stage by minimizing the expectation of quality loss. Then, online controllable variables were adjusted during production according to the measurement of noise variables. Finally, the illustrative example showed that the proposed approach achieved lower quality cost.

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Keywords: Robust parameter control; online controllable variables; offline controllable variables; generalized quality cost

Nomenclature

$\boldsymbol{x}$	controllable variables
$\boldsymbol{X}$/**U**	offline/online controllable variables
$\boldsymbol{\eta}$	noise variables
e/**n**	measurable/immeasurable noise variables
y	process response
k	economic coefficient
$	dollar sign
J	generalized quality cost
L/C	quality loss/manufacturing cost

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1. Introduction

The complex manufacturing process outputs are influenced by the comprehensive influence of many process variables. In general, these variables include controllable variables $\mathbf{x}$, which can be easily controlled, and noise variables $\boldsymbol{\eta}$, which vary randomly and are difficult to operate. If y is a process response, a general statistical model that describes the relationship between $\mathbf{x}$, $\boldsymbol{\eta}$ and y can be expressed as:

$$y = f(\mathbf{x}, \boldsymbol{\eta}) \tag{1}$$

Taguchi's robust parameter design is considered as a cost effective tool for reducing variation of responses, which minimizes the influence of noise variables on process response by choosing proper controllable variables settings[1]. If the controllable variables settings are designed, they will not be adjusted during production. Therefore RPD is essentially an offline control scheme. In reality, although some noise variables are not controllable, maybe they can be measured or estimated during production. Traditional RPD don't make good use of these noise variables' information. Pledger illustrated an approach to enhance the choice of values for the controllable variables by utilizing the available observations of noise variables[2]. Jin and Ding proposed an automatic control strategy based on regression models obtained from design of experiment (DOE) by using measurable noise variables and immeasurable noise variables[3]. Shi et al. presented a robust process control model, where controllable variables are classified into online controllable variables and offline controllable variables[4]. The online controllable variables denote variables that can be adjusted in time, and offline controllable variables denote variables that are set at the design stage and difficult to be adjusted online. Zhong et al. developed the DOE-based automatic process controller scheme that considers both the observation and the modelling uncertainties[5]. The model can achieve better process performance than traditional design, and is more stable than normal DOE-based automatic process controllers. Ye et al. developed a control strategy which is capable of ensuring an acceptable process performance with a reduced adjustment frequency[6]. This approach can reduce the adjustment frequency, but increase the variance.

The aforementioned DOE-based APC approaches are developed based on quadratic loss function, representing the measurements of product quality characteristics deviation from the expected target. The DOE-based APC approach is defined as robust parameter control, which minimize process variability by optimizing offline controllable variables settings and adjusting online controllable variables. All cost incurred in a product life cycle can be divided into two main categories: manufacturing cost which occurs during production and quality loss which occurs after the end of the manufacturing processes [7]. Generalized quality cost includes the cost spending for guaranteeing product quality during production, such as adjusting cost and inspecting cost, and quality loss. However, in practice, the cost of adjusting controllable variables and inspecting is high. It's imperative to select proper controllable variables and to apply these variables to RPC in consideration of generalized quality cost.

In this paper, a generic APC scheme based on experimental design and modelling is developed in consideration of generalized quality cost. Following this introduction, in Section 2, the analysis procedure for determining offline controllable variables and a robust process control model are proposed in consideration of generalized quality cost. The procedure of the robust process control strategy is shown in Fig.1. The Section 3 demonstrates the applicability and validity of the resulting RPC model through a simulation experiment. Finally, some discussions and concluding remarks are summarized in Section 4.