

# Chapter 15

## Optimizing the Performance of Plastic Injection Molding Using Weighted Additive Model in Goal Programming

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### ABSTRACT

*Injection molding process is increasingly more significant in today's plastic production industries because it provides high-quality product, short product cycles, and light weight. This research optimizes the performance of this process with three main quality responses: defect count, cycle time, and spoon weight, using the weighted additive goal programming model. The three quality responses and process factors are described by appropriate membership functions. The Taguchi's orthogonal array is then utilized to provide experimental layout. A linear optimization based on the weighted additive model in goal programming model is built to minimize the deviations of the product/process targets from their corresponding imprecise fuzzy values specified by the process engineer's preferences. The results show that the average defect count is reduced from an average of 0.75 to 0.16. Moreover, the average cycle time becomes 13.06 seconds, which is significantly smaller than that obtained at initial factor settings (= 15.10 seconds). Finally, the average spoon weight is exactly on its target value of 2.0 gm.*

### INTRODUCTION

Plastic injection molding process (Yang & Gao, 2006; Oktem et al., 2007; Huang & Lin, 2008) is one of the most important polymer processing operations in today's plastic production industries for providing short product cycles, high-quality

part surfaces, good mechanical properties, low costs, and light weight.

In practice, the plastic injection molding process consists of four phases, including plastication, injection, packing, and cooling. Recently, investigating the factors affect the performance of this process has gained significant research attention.

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For example, Ong and Koh (2005) investigated the effects of the mold temperature, injection pressure, injection rate, and injection time on the weights of the plastic parts in the micro injection molding process. Song et al. (2007) studied the effects of injection rate, injection pressure, melt temperature, metering size, and part thickness on ultra-thin wall plastic parts in the injection molding process using Taguchi method. Tang et al. (2007) investigated the effects of the melt temperature, filling time, packing pressure, and packing time on reducing warpage in the plastic injection molding process using Taguchi method. Deng et al. (2008) studied the effects of injection time, velocity pressure switch, packing pressure, and injection velocity on product's weight in the injection process by integrating Taguchi method, regression analysis, and the Davidon-Fletcher-Powell method. Chen et al. (2008) employed self-organizing map with back-propagation neural network and Taguchi method to investigate the effects of injection time, packing pressure, injection velocity, and packing time on part's weight. Altan (2010) reduced shrinkage in injection moldings using a hybrid Taguchi and neural network approach by optimizing the weight of the produced part.

However, the above-mentioned research only considered optimizing a single quality response. Recently, optimizing multiple quality responses of the injection molding process has received significant research attention. Among them, Chiang (2007) integrated Taguchi method, back-propagation neural network, genetic algorithm and engineering optimization concepts to optimize the multiple-input and multiple-output plastic injection molding process. Five process factors were investigated including melt temperature, mold temperature, injection velocity, injection pressure, and velocity pressure switch. Three quality responses were studied, including the strength of welding line, shrinkage, and the differences in distributive temperature. Kamoun et al. (2009) used the simplex method to the on-line optimization of the parameters of an injection molding process.

Eight process factors were studied including back pressure, injection rate, injection pressure, cooling time, holding pressure, holding time, nozzle temperature, and opening stroke. The quality responses were cycle time and the percentage of defective.

Typically, determining precise targets for multiple quality responses is often a difficult task for a process/product engineer in the real world. The conventional goal programming (GP) models usually consider the response goals as precise and deterministic. Therefore, several formulations of GP models were introduced for solving the fuzzy GP (FGP) problems taking into account the decision maker's preferences. An effective approach in dealing with FGP is the weighted additive model which takes into account all shapes of membership functions (Yaghoobi et al., 2008). Therefore, this research utilizes the weighted additive model to optimize the performance of an injection molding process for plastic spoons with three quality responses, including defect count, process cycle time and spoon weight. Each quality response is described by a suitable membership function. Also, the process factor levels, which are assigned by process knowledge, are described by a desired operational interval, and hence they are represented by a trapezoid membership function. An optimization model is then formulated to minimize the weighted deviations from the imprecise fuzzy values for all quality responses and process factors. Finally, the optimal factor settings are obtained then the anticipated and confirmation improvements are calculated.

## **INJECTION MOLDING**

### **Identifying Main Quality Responses**

The main idea of the injection molding process is based on forcing molten plastic resins through a nozzle under pressure into a mold having two basic parts. Plastic material fills the space in between

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