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# Multi-objective optimization for multi-stage sequential plastic injection molding with plating process using RSM and PCA-based weighted-GRA

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## Abstract

The multi-stage sequential process with multi-objective is a complex problem to address as the decision made at a particular stage influences the subsequent stage and vice versa. In this article, the effects of input variables of plastic injection, mold, and different plating stages were investigated on different output responses, namely weldline, warpage, length, and various metal plating thicknesses. This paper investigates a real-time industrial data of manufacturing an automotive exterior part made of ABS material. A D-optimal experimental layout with 55 experiments was generated for eight input factors each at three levels. Nine different output responses in each experiment were normalized into a weighted grey relational grade using grey relational analysis coupled with principal component analysis. The solutions obtained by the analysis of variance on weighted grey relational grade, and by the desirability analysis of D-optimal were compared and validated. The confirmation experiments recorded an average improvement in cumulative process outputs as 40.56% by grey relational analysis and 38.50% by desirability analysis.

## Keywords

Sequential process optimization, multi-objective optimization, plastic injection molding, grey relational analysis, principal component analysis

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## Introduction

Plastics are receiving booming respect in the auto industry due to the demand of light weighting and fuel efficiency together with providing durability, corrosion resistance, toughness, design flexibility, resiliency, and high performance at low cost.[1,2] Plastic injection molding (PIM) is one of the most widely used industrial technologies in polymer processing capable of producing parts with complex shapes at a relatively low cost. Many daily use products, e.g. electronic devices, appliances, and packaging, rely on the technology and production of the PIM industry,[3] which covers approximately 32% of all plastic components.[4,5] PIM process consists of four different phases, namely, plastication, injection, packing, and cooling.[6] All these phases are dependent on each other to produce quality products with reduced cycle time and high productivity. PIM consists of many process parameters such as mold temperature, melt temperature, injection time, injection pressure, packing time, packing pressure, and cooling time. The complexity of the process makes it difficult since sufficient knowledge about mold design, polymer properties, and process parameters is required to manufacture a high-quality part with a suitable cost and time efficiency.[7] The inappropriate process parameters easily cause major defects such as warpage, shrinkage, air traps and weld lines, sink mark, and short shot, so it is essential to determine the optimal process parameters to minimize these defects. Shrinkage is influenced by the lack of dimensional stability of the part, cooling system, flow-induced residual stresses, flow-induced crystallization, and orientation. Warpage is induced due to nonuniform molding temperatures or cooling rates, nonuniform packing pressures. Weld line is the weakest area of any molded plastic. It is bound to

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