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Technical Report

Optimization of injection molding process parameters using sequential simplex algorithm

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ABSTRACT

In this study warpage and shrinkage as defects in injection molding of plastic parts have been undertaken. MoldFlow software package has been used to simulate the molding experiments numerically. Plastic part used is an automotive ventiduct grid. The process optimization to minimize the above defects is carried out by sequential simplex method. Process design parameters are mold temperature, melt temperature, pressure switch-over, pack/holding pressure, packing time, and coolant inlet temperature. The output parameters aside from warpage and shrinkage consist of part weight, residual stresses, cycle time, and maximum bulk temperature. Results are correlated and interpreted with recommendations to be considered in such processes.

1. Introduction

Many products in different areas such as aviation, automotive, electronic apparatus are produced using plastic injection molding. Having special features like capability to produce complex parts, light weight, resistance to corrosion, ease of producing compared to conventional materials, are the main reasons for their popularity. High quality and precision can be achieved using this method for manufacturing plastic parts. The need for lighter, more aesthetic and durable products necessitates manufacturing thinner parts. Since most molten plastics cannot fill the mold cavity of thin walled parts suitably, plastic injection molding need be used which can result in warpage [1]. Therefore, reduction and control of warpage is of importance in enhancement of the quality. Hence, warpage minimization plays a key role in the product optimization. As the thickness decreases, the strength is also weakened. Therefore, ultimately the problem can be solved using the right kind of material for the purpose of durability.

Ordinarily, production shop operators can adjust only one process parameter at a time and this does not necessarily lead to the real optimum combination of process parameters. This is particularly true when the objective function like warpage and/or volumetric shrinkage is an implicit function of the control variables and possible interaction among them.

Warpage and volumetric shrinkage as major defects in such manufactured parts are subject to change by the shape of parts, modifying the mold and having different sets of process parameters. The design of mold and part are usually considered in the very start of design procedure and remain unchanged. Consequently, determination of the best set of process parameters a priori by an optimization procedure is the best way for minimization of such defects [1–3].

In this field some researchers have focused on finding surrogate models like support vector regression, neural network and polynomial regression in lieu of expensive and time-consuming experimentations. These surrogate models are considered as a mathematical approximation replacing the actual simulation analyses. Using response surface method and neural network model, Erzurumlu made reduction in warpage in thin shell plastic parts [4]. Kurtaran et al. optimized warpage for a bus ceiling lamp casing utilizing genetic algorithm and neural network model [5]. Zhou et al. used support vector regression for optimization of injection molding process [6]. Shen et al. optimized process parameters for reducing maximum volumetric shrinkage difference using genetic algorithm and neural networks [7].

These papers apparently show that surrogate models are good approximations of the actual ones reducing time and computational cost. However, these surrogate models are classified as one-step optimization, without iterations. Therefore, the accuracy of the surrogate models determines how accurate the optimum solution is.

Since it is a time-consuming work to optimize warpage and volumetric shrinkage, an efficient optimization method called "sequential simplex" optimization is used here; a zero order optimization method not requiring any gradient computations. In this paper, we firstly introduce sequential simplex optimization method, and subsequently the working models.

Huang and Tai stated that the most crucial factors that affect warpage in injection molding of a thin shell part are packing pressure, mold temperature, melt temperature and packing time [8]. However, since minimization of both warpage and volumetric

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