Research Paper

Volume : 2 | Issue : 5 | May 2013 • ISSN No 2277 - 8179

Plastic Injection Molding with Taguchi Approach - A Review

Engineering

KEYWORDS : Warpage, Shrinkage, Plastic Injection Molding, Robust Design, Taguchi Parameter Design, Orthogonal arrays, Signal-To-Noise Ratio

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ABSTRACT

Plastic injection molding comprises plastication, injection, packing, cooling, and ejection and process/part quality control applications. These steps are followed for the parts, which are designed by CAD & to be produced by plastic injection method. A competent mold designer must have a thorough knowledge of the principles of mold making as the design of the various parts of the mould depends on the technique adopted for its manufacture. This paper deals with the literature review on study of application of taguchi method. The Taguchi robust parameter design has been widely used over the past decade to solve many single response process parameter designs. Taguchi optimization method was used by exploiting mold analyses based on two level factorial design. Orthogonal arrays of Taguchi, the signal-to-noise (S/N) ratio are utilized to find the optimal levels and the effect of process parameters are determined by many researchers on shrinkage & warpage.

I. INTRODUCTION

Plastic Injection Molding is a high precision tool that is being used to mass produce plastic parts to cater to industries such as those in the consumer and electronics, automotive and medical sector. However, costly tooling and machinery are needed in this manufacturing process. Due to the many delicate adjustment required,it is most complex processes.The product quality depand on mold design, material selection, and process parameter setting.Plasticization, cooling, packing, injection are the phase of injection molding process[1]. Incorrect input parameters settings will cause bad quality of surface roughness, decreases dimensional precision, warpage, unacceptable wastes, increases lead time and cost [2]. Hang et al. [3] considered six input parameters as; melting temperature, mold temperature, packing pressure, packing time injection time and packing pressure. They studied effects of these parameters on surface quality of the thin molded parts. Li yang et al. [4] investigated effect of the same parameters with the addition of injection speed, injection acceleration on width of the segregation line. Chang et al. [5] studied effects of melting temperature, injection temperature, packing time and packing pressure on the surface quality of the produced parts using fuzzy logic. Sue et al. [6] used Artificial Neural Network (ANN) and SA algorithm to optimized surface quality of produced parts. Shi et al. [7] used numerical simulation and Genetic Algorithm (GA) to achieve best shear stress. Warpage in plastic parts due to anti-symmetric shrinkage is one of the most important defects caused by residual stress. These stresses are usually due to the one directional anti-symmetric shrinkage. As the shrinkage decreases, shrinkage in 3 directions decrease and therefore warpage decreases [8].

II. LITERATURE REVIEW

Plastic injection molding, the polymer analogue of die casting for metals, is the most widely used technique for fabricating thermoplastic materials. It is a high rate production process, with good dimensional control. Moreover, this is a net-shape process, so highly complex components can be produced in the finished state. Plastic injection molding (PIM) has many advantages such as short product cycles, high quality part surfaces, good mechanical properties, low cost, and light weight, so it is becoming increasingly more significant in today's plastic production industries. Costs can be reduced further by the integration of components, while there is the potential for weight savings over metal counterparts. A finely pelletized or granulized plastic is forced, at an elevated temperature and by pressure, to flow into, fill and absorb the shape of a mold cavity as shown in figure-1.[9].

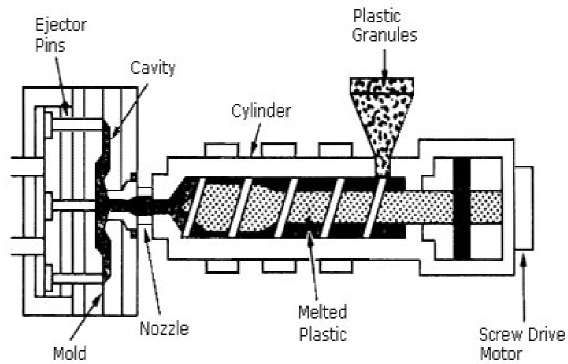

Fig. 1. Plastic Injection Molding Machine

Plastic injection processes comprise plastication, injection, packing, cooling ejection and process/part quality control applications [10]. During production, quality problems of the plastic parts are effected from manufacturing process conditions. One of the most important quality problems is warpage [11-13]. Casab [14] demonstrates that, the Taguchi method is a capable of establishing an optimal design configuration, even when significant interactions exist between and among the control variables. The Taguchi method can also be applied to designing factorial experiments and analyzing their outcomes. Factorial experiments is an experiment whose design consist of two or more factors, each with discrete possible values or levels, and whose experimental units take on all possible combinations of these levels across all such factors. Factorial experiments can be used when there are more than two levels of each factor. Taguchi parameter are used for optimizing the parameters and to obtain the minimum warpage. Huang and Tai [15] determined the most effective factors regarding warpage in injection molding of a thin shell part such as packing pressure, mold temperature, melt temperature and packing time injection parameters. Taguchi method is also strong tool for the design of high quality systems. To optimize designs for quality, performance and cost, Taguchi method presents a systematic approach that is easy to use and effective. Taguchi extensively uses experimental design primarily as a tool to design products more robust (which mean less sensitive) to noise factors.

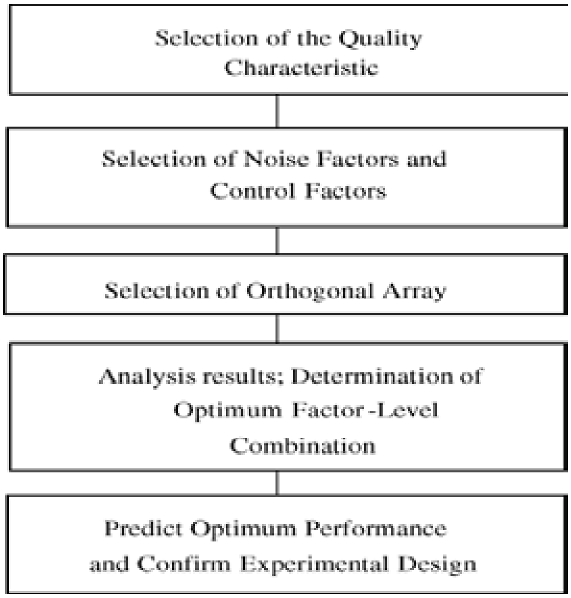

Fig. 2. Steps of Taguchi parameter design.

Kevin Alam et al [16] Robust design is an engineering methodology for optimizing the product and process conditions which are minimally sensitive to the various causes of variation, and which produce high-quality products with low development and manufacturing costs. Hence, Taguchi developed manufacturing system that were robust or insensitive to daily or seasonal variations of environment, machine wear, and other external factors. Taguchi's parameter design is an important tool for robust design. His tolerance design can be also classified as a robust design. In a narrow sense robust design is identical to parameter design, but in a wider sense parameter design is a subset of robust design. Robust optimization methods account for the effects of process variation by simultaneously optimizing the objective function and minimizing its sensitivity to parameter variation. Figure:2 demonstrate the step of taguchi parameter design.

III. TAGUCHI APPROACH
Two important tools are also used in parameter design are signal-to-noise (S/N) ratios and orthogonal arrays.

Orthogonal arrays allow researcher or designer to study many type of design parameters and can be used to estimate the effects of each factor independent of the other factors. Orthogonal Arrays (OA) are a special set of Latin squares, constructed by Taguchi to lay out the product design experiments. By using this table, an orthogonal array of standard procedure can be used for a number of experimental situations. Consider a common 2-level factors OA as shown in table 1 below:

Orthogonal Array $L_8\,(2^7)$

FACTORS
Table 1. An orthogonal array of L8.

TRIAL NO.	A	B	C	D	E	F	G
1	0	0	0	0	0	0	0
2	0	0	0	1	1	1	1
3	0	1	1	0	0	1	1
4	0	1	1	1	1	0	0
5	1	0	1	0	1	0	1
6	1	0	1	1	0	1	0
7	1	1	0	0	1	1	0
8	1	1	0	1	0	0	1

The array is designated by the symbol L8, involving seven 2-level factors, zeros and ones. The array has a size of 8 rows and 7 columns. The number (zeros/ones) in the row indicate the factor levels (be it a fluid viscosity, chemical compositions, voltage levels, etc.) and each row represents a trial condition. The vertical columns represents the experimental factors to be studied. Each of the assigned columns contain four levels of zeros(0), and four levels of ones(1), these conditions, can combine in four possible ways, such as (0,0), (0,1), (1,0), (1,1,), with 27 possible combinations of levels. The columns are said to be orthogonal or balanced, since the combination of the levels occurred the same number of times, when two or more columns, of an array are formed. Thus, all seven columns of an L array, are orthogonal to each other.

(ii) The signal-to-noise ratio is a quality indicator by which the experimenters and designers can evaluate the effect of changing a particular design parameter on the performance of product. There are 3 Signal-to-Noise ratios of common interest for optimization of Static Problems;

SMALLER-THE-BETTER :
$n = -10\ \mathrm{Log}_{10}$ [mean of sum of squares of measured data]

This is usually the chosen S/N ratio for all undesirable characteristics like " defects " etc. for which the ideal value is zero. Also, when an ideal value is finite and its maximum or minimum value is defined (like maximum purity is 100% or maximum Tc is 92K or minimum time for making a telephone connection is 1 sec) then the difference between measured data and ideal value is expected to be as small as possible. The generic form of S/N ratio then becomes,

$n = -10\ \mathrm{Log}_{10}$ [mean of sum of squares of {measured - ideal}]

LARGER-THE-BETTER :
$n = -10\ \mathrm{Log}_{10}$ [mean of sum squares of reciprocal of measured data]

This case has been converted to SMALLER-THE-BETTER by taking the reciprocals of measured data and then taking the S/N ratio as in the smaller-the-better case.

NOMINAL-THE-BEST :
$n = 10\ \mathrm{Log}_{10}$(square of mean / variance)

This case arises when a specified value is MOST desired, meaning that neither a smaller nor a larger value is desirable [17-21].

The Taguchi Approach is popular not only in the design stage, but also applicable during manufacturing stage for improving processes which reduce the variation. Having a certain degree of refinement without being too mathematical, the methodology should be readily understandable to engineers.

IV. CONCLUSION
This study was focused on the application of Taguchi optimization technique to find the optimum levels of process parameters used in injection plastic components for those part by improving the warpage problem with shrinkage variation. Warpage is one of the main defects in injection molding process which appears due to anti-symmetric shrinkage. In doing this, the orthogonal arrays, the S/N ratio were utilized in integrated manner. By using the taguchi method we can optimize the injection process parameters, using optimum process parameters we can achieve minimum shrinkage, which reduces the maximum warpage of plastic component.

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