PROCESS PARAMETER OPTIMIZATION OF PLASTIC INJECTION MOULDING BY TAGUCHI METHOD : A REVIEW

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Abstract— **Injection molding has been a challenging process for many manufacturers and researchers to produce products meeting requirements at the lowest cost. Faced with global competition in injection molding industry, using the trial and-error approach to determine the process parameters for injection molding is no longer good enough. Factors that affect the quality of a moulded part can be classified into four categories: part design, mold design, machine performance and processing conditions. The part and mold design are assumed as established and fixed. During production, quality characteristics may deviate due to drifting or shifting of processing conditions caused by machine wear, environmental change or operator fatigue. Determining optimal process parameter settings critically influences productivity, quality, and cost of production in the plastic injection molding (PIM) industry. Previously, production engineers used either trial-and-error method to determine optimal process parameter settings for PIM. However, this method is unsuitable in present PIM because of the increasing complexity of product design and the requirement of multi-response quality characteristics. The choice of DOE strategy (Taguchi or Classical DOE) depends a great deal on the degree of optimization required, resolution required, time and cost constraints, nature of the problem and they are illustrates the power of Taguchi approach to DOE. This concurred with the given references of the power of using Taguchi approach because this method is robust design, and they also apply the same method in optimization parameter injection molding plastic part.**

Keywords— Taguchi method, Minitab, PIM (Plastic injection molding, DOE.

I. INTRODUCTION

THIS paper attempts to describe the optimization of the injection molding process parameter for optimum shrinkage performance of a plastic tray which is made from polymer blends or poly blends. Process optimization is the discipline of adjusting a process so as to optimize some specified set of parameters without violating some constraint. The most common goals are minimizing cost, maximizing throughput, and/or efficiency. This is one of the major quantitative tools in industrial decision making. When optimizing process, the goal is to maximize one or more of the process specifications, while keeping all others within their constraints.

The choice of DOE strategy (Taguchi or Classical DOE) depends a great deal on the degree of optimization required, resolution required, time and cost constraints, nature of the problem and they are illustrating the power of Taguchi approach to DOE. This concurred with the given references of the power of using Taguchi approach because this method is robust design, and they also apply the same method in optimization parameter injection molding plastic part.

1.2 TAGUCHI TECHNIQUE

Taguchi methods are statistical methods developed by Genichi Taguchi to improve the quality of manufactured goods, and more recently also applied to engineering, biotechnology, marketing and advertising. Professional statisticians have welcomed the goals and improvements brought about by Taguchi methods,[editorializing] particularly by Taguchi's development of designs for studying variation, but have criticized the inefficiency of some of Taguchi's proposals.

Taguchi's work includes three principal contributions to statistics:

- A specific loss function
- The philosophy of off-line quality control; and
- Innovations in the design of experiments. (DOE)

1.3 TAGUCHI'S RULE FOR MANUFACTURING

Taguchi realized that the best opportunity to eliminate variation is during the design of a product and its manufacturing process. Consequently, he developed a strategy for quality engineering that can be used in both contexts. The process has three stages:

1. System design
2. Parameter (measure) design
3. Tolerance design

System design
This is design at the conceptual level, involving creativity and innovation.

Parameter design

Once the concept is established, the nominal values of the various dimensions and design parameters need to be set, the detail design phase of conventional engineering. Taguchi's radical insight was that the exact choice of values required is under-specified by the performance requirements of the system. In many circumstances, this allows the parameters to be chosen so as to minimize the effects on performance arising from variation in manufacture, environment and cumulative damage. This is sometimes called Robustification.

Robust parameter designs consider controllable and uncontrollable noise variables; they seek to exploit relationships and optimize settings that minimize the effects of the noise variables.

Tolerance design

With a successfully completed parameter design, and an understanding of the effect that the various parameters have on performance, resources can be focused on reducing and controlling variation in the critical few dimensions.
Helpful Hints

2.1 LITERATURE REVIEW

Tao c. Chang and Ernest Faison et al [1] Has applied the Taguchi method to systematically identify the significance of seven injection parameters and their effects on the appearance (width) of weld lines. The contributions of each factor to the quality and the optimum condition were identified. The optimal condition for weld line appearance was experimentally verified.

Shaikh mohammad mohammad yusoff et al [2] This paper illustrates an application of design of experimental (DOE) approach in an industrial setting for identifying the critical factors affecting a plastic injection molding process of a certain components for aircond assembly. The five process parameters are back pressure, screw rotation, spear temperature, manifold temperature and holding pressure transfer.

Wen-Chin Chen et al [3] In this paper Taguchi parameter design methods is applied with back-propagation neural networks, genetic algorithms, and engineering optimization concepts, to optimize the initial process settings of plastic injection molding equipment's. The research result indicates that the proposed approach can effectively help engineers determine optimal initial process settings, reduce set-tests iterations, and achieve competitive advantages on product quality and costs. They have used Taguchi's parameter design methods with back-propagation neural networks, genetic algorithms, and engineering optimization concepts, to optimize the initial process settings of plastic injection molding equipment.

Wen-ChinChen Tung-Tsan Lai et al [4] In this paper, Taguchi method, back-propagation neural networks (BPNN), and genetic algorithms (GA) are applied to the problem of process parameter settings for multiple-input

Single-output (MISO)plastic injection molding. Taguchi method is adopted to arrange the number of experimental runs. Injection time, velocity pressure switch position, packing pressure and injection velocity are engaged as process control parameters and product weight as the target quality. Then, BPNN and GA are applied for searching the final optimal parameter settings. Two confirmation experiments are performed to verify the effectiveness of the proposed approach. Experimental results reveal that the proposed approach not only can avoid shortcomings inherent in the commonly used Taguchi method but also can result in significant quality and cost advantages. Taguchi method, back-propagation neural networks (BPNN), and Genetic algorithms Lahoti, et al,

Alireza Akbarzadeh et al [5] In this study, effect of injection molding parameters on shrinkage in polypropylene (PP) and polystyrene (PS) is investigated. The relationship between input and output of the process is studied using regression method and analysis of variance (ANOVA) technique. To do this, existing data is used. The selected input parameters are melting temperature, injection pressure. Effect of these parameters on the shrinkage of above mentioned material is studied using mathematical modelling. For modelling the process, different types of regression equation including linear polynomial, quadratic polynomial and logarithmic functions are used to interpolate experiment data. Next, using step backward elimination and 95% confidence level (CL), insignificant parameters are eliminated from the model. To check validity of the pp model, correlation coefficient of each model is calculated, and the best model is selected. The same procedure is repeated for the PS model. Finally, optimum levels of the input parameters that minimize shrinkage for both materials are determined.

Velia Garc´ıaLoera, et al [**6**] Has done study to set the process variables in a thermoplastic injection molding operation in considering multiple criteria in a simultaneous manner. The task has approached through the application of an optimization strategy based on data envelopment analysis (DEA).

D mathivanan et al [7] optimal setting up of injection molding process variables plays a very important role in controlling the quality of the injection molded products. It is all the most important to control attribute defects like sink marks. Sink marks are basically a design in problem and hence it is to be attended during design stages. Owning to certain condition and constraints, sometimes, it is rather ignored during design stages and it is expected to be handled by molders with only instruction to do the best. Handling of numerous processing variables to control defects is a mammoth task that cost time, effort and money. This paper presents a simple and efficient way to study the influence of injection molding variables on sink marks using Taguchi approach. Using the Taguchi approach, optimal parameters settings and the respective sink depth were arrived. The sink depth based on validation trials was compared with the predicted sink depth and they are found to be in a good arrangement. The result demonstrates the ability of this approach to predict sink depth for various combination of processing variables with in the design space.

Zhao Longzhi et al [8] In this paper, they have analyzed multi-molding process parameters by the combination of orthogonal experiments and mold flow simulation tests. In this paper in order to avoid the surface sink marks on the automobile dashboard decorative covers, the combined effects of multi-molding process parameters are analysed by the combination of orthogonal experiments and mold flow simulation tests.

Kamaruddin et al[9] This paper presents a study in which an attempt has been made to improve quality characteristics (shrinkage) of an injection molding products (plastic tray) made from blends plastic (75% POLYPROPYLENE (PP) and 25% LDPE (LOW DENSITY POLYETHYLENE)**.**They have optimized the injection molding process parameters such as injection speed, injection pressure, holding pressure, melting temperature, holding time, cooling time using the Taguchi method. For improve the quality characteristic (shrinkage) of an injection molding product.

A.H.Ahmad et al [10] It has analyzed the warpage defect on Acrylonitrile Butadiene Styrene (ABS). The approach was based on Taguchi's Method and Analysis of Variance (ANOVA) to optimize the processing parameters namely packing pressure, mould temperature, melt temperature and packing time for effective process. The phenomenon of `Shrinkage' of the plasticized material while cooling leads to allied molding defects like warpage, sink marks along with the need to have a higher draft on the walls of the mold. Uneven shrinkage (due to uneven cooling / uneven sections) leads to warpage and sink marks. At present, the shrinkage is known for every variant of the plastic material with or without fillers. `Packing' is normally employed as a counter remedy for shrinkage. Though, there exists a solution, there is no defined method for arriving at the molding parameters that should be controlled for a certain variety of plastic and a certain configuration of a component. Development of injection molded component with focus over the molding parameters like melt temperature, injection pressure, injection velocity, injection time, packing pressure, packing time, cooling temperature, and cooling time to optimize the development cycle for the component. Current industrial practice: Customized approach based on experience for setting parameters

2.3 GAP ANALYSIS

From the above literature review, integrating following points:

[1] There is number of cycle time which can affects quality and productivity.
[2] Need to develop appropriate operations for optimizing parameters.
[3] Requirement of adequate pressure and temperature to minimize the warpage at the end of product.

3.1 PROBLEM DEFINITION:

1.Determining optimal initial process parameter settings critically influences productivity, quality, and costs of production in the plastic injection molding (PIM) industry.

2. The trial-and-error process is costly and time consuming.

3. The problem for the proposed work is to discern the optimal values for the injection molding parameters.

4.The reference chart so evolved during the dissertation work would prove handy while deliberating over the actual process/ production plan for any newly introduced component"

3.2 OBJECTIVE:

To study the injection molding process parameters for two different thermoplastic materials.
To Develop a methodology to produce defects free parts by controlling the initial process parameters settings (like melt temperature, injection pressure, injection velocity, injection time, packing pressure, packing time, cooling temperature, cooling time, etc). Identify the critical parameters that need the longest time for iteration for study.
To provide a common ground for recommendation of processing parameters settings according to geometrical and the material characteristics of the injection molded component.

3.4 EXPERIMENTATION:

The experimentation will be carried out over a suitable molding machine based on the tonnage requirement for the subject components. The mold should be functional and the study should be carried out for current parts under production. Materials to be included in the study would be thermo-plastic materials. Document the data for research and analysis further using DOE. Taguchi optimization method will used to evaluate best possible combination of the injection molding process parameters like melt temperature, injection pressure, injection velocity, injection time, packing pressure, packing time, cooling temperature, cooling time.

3.5 VALIDATION:

The process chart standardized with the values for the process variables will be validated for the upcoming automotive components that are awaiting pilot run of production. The process would be repeated for the variants to ensure consistency in the physical characteristics of the component produced. Validation will be carried out by bring out actual development of two components. Trials and testing would address the phase of validation as the mould would be tried out for checking the nature of the physical components as an outcome of the development process.

3.6 SOFTWARE:

Use of minitab for DOE (Taguchi method): The use of this software would highlight the recommended values of the parameters for Injection Molding for the specified component design.

3.7 EXPECTED OUTCOME

1. Optimization of four parameters such as injection speed, injection pressure, holding pressure melting temperature, holding time, cooling time.
2. Reducing required cycle time**.**

Conclusion

A conclusion section is not required. Although a conclusion may review the main points of the paper, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions.

Appendix

Appendixes, if needed, appear before the acknowledgment.

Acknowledgment

The preferred spelling of the word "acknowledgment" in American English is without an "e" after the "g." Use the singular heading even if you have many acknowledgments. Avoid expressions such as "One of us (S.B.A.) would like to thank ... ." Instead, write "F. A. Author thanks ... ." Sponsor and financial support acknowledgments are placed in the unnumbered footnote on the first page.

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