Practical application of Taguchi method for optimization of process parameters in Injection Molding Machine for PP material

ANAND KR DWIWEDI, SUNIL KUMAR

[1] *M.TECH. Scholar, Mechanical Engineering, Samalkha Group of Institution affiliated to Kurukshetra University Kurukshetra, Haryana,India*

[2]*Assistant Professor,Mechanical Engineering, Samalkha Group of Institution, affiliated to Kurukshetra University Kurukshetra, Haryana,India*

---***---

Abstract- *Injection molding is a very popular polymer processing methods due to its high production rate as well as its ability to produce complex shapes of plastic product at very cheaper cost and in a limited period of time. The old concept of using the trial and error method to determine the process parameters for injection molding machine is no longer good enough because the complexity of product design is now increased and the requirement of multi-response quality characteristics is needed. For Determining optimal process parameter settings critically influences productivity, quality, and cost of production in the plastic injection molding industry. This article aims to analyze the recent research in determining optimal process parameters of injection molding machine. A large number of research works based on various approaches have been performed to obtain the optimal process parameter setting for injection molding machine. These approaches, including mathematical models, Taguchi method, Artificial Neural Networks, Fuzzy logic, Case Based Reasoning , Genetic Algorithms, Finite Element Method, Non Linear Modeling, Response Surface Methodology, Linear Regression Analysis ,Grey Rational Analysis and Principle Component Analysis .*

The difficulty of optimizing an injection molding process is that the performance measures usually show conflicting behavior. Therefore, a compromise must be found between all of the performance measures of interest. In this paper injection molding process parameter optimization for polypropylene material has been done using the Taguchi methodology. This methodology provides the optimum value of process parameter with the help of orthogonal array by conducting only few experiments. We used Processing temperature, Injection pressure, Cooling time and Injection speed as a process parameter and optimized the process parameters by considering Tensile strength as a resulting factor.

Key Words: optimum value, and orthogonal array, process parameter etc…

1. Introduction

Injection molding is one of the most important shape forming processes for thermoplastic polymer. Maximum amount of all the plastic products are manufactured by injection molding machine. Injection molding machine is best suited for manufacturing large numbers of plastic products of complex structure and sizes. In the injection molding process, hot melted plastic is forced into a mold (which is relatively at lower temperature). Then, the hot melt is allowed to solidify for some time. After Solidified net shape product is ejected outside when the mold open. Although the process is very simple, prediction of final part quality is a difficult task due to the large number of process variables.

M.C. Huang and C.C. Tai [1] studied the effect of five input parameters like mould temperature, melting temperature, packing pressure, packing time and injection time on surface quality of thin molded plastic parts. Altan [2] optimized shrinkage of plastic material like Polypropylene and Polystyrene in injection molding machine using Taguchi methodology. Alten also used concept of the neural network to model the process and was able to achieve 0.94% and 1.24 % shrinkage in Polypropylene and Polystyrene respectively. Neeraj Singh C [3] presented the cycle time reduction concept and successfully applied on to the injection molding machine for DVD manufacturing by optimizing the parameter of injection molding machine. He optimized the process parameters like effective distance travel & speed the cycle time while manufacturing DVD by injection molding machine in this way the quality of the product is improved and cycle time is also reduced. Similarly he found that the the cooling time and hold time are also effective parameters to reduce cycle time. Alireza Akbarzadeh and Mohammad Sadeghi [4] applied the concept of ANOVA after studying the relationship between input and output of the process. He used four different parameters like melting temperature , packing pressure, packing time and injection time input parameters and by conducting the various experiment finally he realized that the that packing pressure is the most effective process parameter, while injection pressure is the least important parameter for Polypropylene material. Vaatainen et al. [5] observed the effect of the injection moulding process parameters on the visual quality of moldings using the Taguchi optimization method. He realized on the shrinkage with three more defect characteristics like less weight, weld lines and sink marks. He was able to optimize many quality characteristics with very few experiments, which could lead to economical pattern. Mohd. Muktar Alam, Deepak Kumar [6] He determined method to minimize the shrinkage with the help of selection of optimal process parameter injection molding condition by the DOE technique of Taguchi methods. The most effective process parameter was packing pressure out of the packing time,injection pressure and melt temperature Gang XU, Fangbao Deng [7] presented a neural network-based quality prediction system which was an innovative system for a plastic injection molding process. The particle swarm optimization algorithm (PSO) is analyzed and an adaptive parameter-adjusting PSO algorithm based on the velocity information (APSO-VI) is put forward. Experimental results proved that APSO-VINN can better predict the quality (volume shrinkage and weight) of plastic product and can likely be used for a lot of practical applications. From the literature review, it can be concluded that, in order to minimize such defects and to improve the productivity in plastic injection molding processing condition, design of experiment by Taguchi optimization method can be successfully applied and is considered suitable by many researchers. In experimental design strategy, there are many variable factors that affect the various important characteristics of the product. Design parameter values that minimize the effect of noise factors on the product's quality are to be determined. In order to find optimum levels, L9 orthogonal arrays are used. In this way, an optimal set of process conditions can be obtained and the process parameter which is most effective as per tensile strength is determined with the help of conducting only nine experiments.

1.1 Taguchi's Concept

Taguchi's concept is based on the effective application of engineering approach rather than advanced statistical analysis. It focused on both upstream and shop-floor quality engineering concept. Upstream methods effectively reduce the cost and variability by use of small-scale experiments, and used robust designs for large-scale production and market aspect. Shop-floor techniques facilitate economical, real time methods for monitoring and maintaining quality aspects in production. The farther upstream a quality method is applied, the greater leverages it produces on the improvement, and the more it reduces the cost and time. The cost of quality should be measured as a function of deviation from the standard and the losses should be measured system-wide. Taguchi proposes an off-line strategy for quality improvement as an alternative to an attempt to inspect quality into a product on the production line. He observes that poor quality cannot be improved by the process of inspection, screening and salvaging. No amount of inspection can put quality back into the product. Taguchi recommends a three-stage process: system design, parameter design and tolerance design.

His approach gives a new experimental strategy in which a new developed form of design of experiment is used. In other words, the Taguchi approach is a form of DOE with some new and special application approach. This technique is helpful to study effect of various process parameters (variables) on the desired quality and productivity in a most economical manner. By analyzing the effect of various process parameters on the results, the best factor combination taken [10]. Taguchi designs of experiments using specially designed tables known as "orthogonal array". With the help of these experiments table the design of experiments become the use of these tables makes the design of experiments very easy and consistent [11] and it requires only few number of experimental trials to study the entire system. In this manner the whole experimental work can be made economical. The experimental outcomes are then transformed into a S/N ratio. Taguchi suggest the use of the S/N ratio to investigate the quality characteristics deviating from the standard values. Usually, there are three type of classification of the quality characteristic in the study of the S/N ratio, i.e. the-lower-the better, the-higher-the-better, and the nominal-the-better. The S/N ratio for each category of process parameters is computed based on the S/N analysis. Regardless of the category of the quality characteristic, a greater S/N ratio corresponds to better quality characteristics. Therefore, the optimum level of the process parameters is the level with the greatest S/N ratio, so in this manner the optimal combination of the process parameters can be predicted.

1.2 Process parameters

There are a number of machine settings that allows the control of all steps of slurry or melt preparation, injection in to a mold cavity and subsequent solidification. Some important parameters of them are like Injection pressure, Injection speed, mold temperature, Processing Temperature; hold pressure, Back pressure, Hydraulic oil temperature, Cooling time, Suck back pressure etc. Among all of these process parameters we have selected Injection Pressure, Injection speed, processing temperature and cooling time as process parameters

2. Experimentation

2.1 Selection of process parameters

There are a number of machine settings that allows the control of all steps of slurry or melt preparation, injection in to a mold cavity and subsequent solidification. Proper selections of all the process parameter put direct impact on the quality and productivity of the plastic product so by considering all these factors some important process parameters like Processing temperature, Injection pressure. Cooling time and Injection speed are selected and for conducting the experiments some set of definite values of all the process parameters are taken in the Table-1. The values of process parameters are taken by the proper discussion with the industry and CIPET personals. After confirming about the significance of all the process parameters the values of the process parameters are listed as a table.

S.NO.	Process Parameters	Unit	Level 1	Level 2	Level 3
1	Processing temperature	°C	180	200	220
2	Injection pressure	MPa	120	130	140
3	Cooling time	sec.	10	15	20
4	Injection speed	mm/sec	50	70	90

TABLE:1 Selected values of process parameter

2.2 Orthogonal Array Preparation & Determination of S/N ratio

After selection of definite values of the process parameter L9 orthogonal array has been selected depending upon the total degrees of freedom for the parameters. Plastic injection molding experiments were carried out on a JSW 180 Fully Automatic Electrical Injection molding machine .

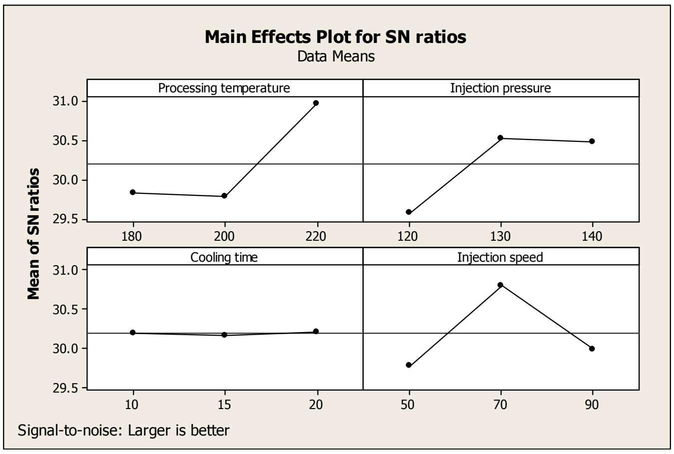
FIGURE: "JSW 180" Injection molding machine

For conducting the experiments the setting of the process parameters has been done as per the given values in Table-1

S. N.	A (P.T.)	B (I.P.)	C (C.T.)	D (I.S.)	T.S.	SNR
1	180	120	10	50	27.67	28.1
2	180	130	15	70	34.67	30.75
3	180	140	20	90	31.33	29.91
4	200	120	15	90	28	28.93
5	200	130	20	50	30.67	29.72
6	200	140	10	70	34.33	30.69
7	220	120	20	70	36	30.98
8	220	130	10	90	36.33	31.10
9	220	140	15	50	35	30.83

TABLE-2: Experimental result for Tensile strength and S/N ratio

Here in the Table -1 nine set of experiment has been designed for selected process parameters like Processing temperature (A), Injection pressure (B), Cooling time (C) and Injection speed (D) as per the Taguchi L9 orthogonal array design system, for optimization of process parameters Tensile Strength (T.S.) is considered as a result parameter and hence it is measured and signal to noise ratio has been calculated for all the nine experiments.



Graph -1: Main effects plot for S/N Ratio

Level	A (P.T.)	B(I.P.)	C(C.T.)	D(I.S.)
1	29.83	29.58	30.20	29.79
2	29.78	30.53	30.17	30.81
3	30.97	30.48	30.21	29.98
Delta	1.19	0.95	0.04	1.02
Rank	1	3	4	2

TABLE-3: Response Table for S/N Ratio

3. CONCLUSIONS

The response table of the S/N ratio is given in table 3, and the best set of combination parameter can be determined by selecting the level with highest value for each factor. As a result, the optimal process parameter combination for PP is A3, B2, C3, D2.The difference value given in table 5 denotes which factor is the most significant for Tensile strength of PP, Processing Temperature (A) is found most effective factor for PP followed by Injection speed (D) Injection Pressure (B),) and cooling time (C).

REFERENCES

[1] M.C. Huang and C.C. Tai , "The effective factors in the warpage problem of an injection-moulded part with a thin shell feature", *J. Mat. Proc. Tech., vol. 110, 2001,pp.1–9.*

[2] M. Altan, "Reducing Shrinkage in Injection Moldings via the Taguchi, ANOVA and Neural Network Methods", j. Mat. & Design, vol. 31,2010, pp. 599–604.

[3] Neeraj Singh Chauhan and Shahzad Ahmad " Optimization of Cycle Time of DVD-R Injection Moulding Machine" by International Journal of Engineering and Technology (IJEST).

[4] Alireza Akbarzadeh and Mohammad Sadeghi "Parameter Study in Plastic Injection Moulding Process using Statistical Methods and IWO Algorithm", *International Journal of Modeling and Optimization, Vol. 1,No. 2, June 2011.*

[5] Vaatainen O, Pentti J. " Effect of processing parameters on the quality of injection moulded parts by using the Taguchi Parameter design method", Plast Rubber Compos 1994;21:2117

[6] Mohd. Muktar Alam, Deepak Kumar "Reducing Shrinkage in Plastic Injection Moulding using Taguchi Method in Tata Magic Head Light" International Journal of Science and Research (IJSR).

[7] Gang XU1, Fangbao Deng 2, Yihong XU "Adaptive Particle Swarm Optimization-Based Neural Network in Quality Prediction for Plastic Injection Moulding " Journal of Computational Information Systems2011

[8] James Anderson, Aaronn K. Ball "Cycle Time Reduction for Optimization of Injection Moulding Machine parameters for Process Improvements" in Session 105-039

[9] Taguchi G, Introduction to quality engineering. New York; Mc Graw Hill;1990.

[10] Roy, R.K., 2001, "Design of Experiments using The Taguchi Approach:16 Steps to Product and Process Improvement". John Wiley & Sons,Inc.

[11] R.K., 1990, *"A Primer on the Taguchi method".* Competitive Manufacturing Series, Van Nostrand Reinhold,NewYork.