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Optimisation of Process Parameters for L.D.P.E. Material in Injection Moulding Machine using Taguchi Methodology

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Abstract- **Injection Moulding is an important polymer processing methodology in the plastic industry. It is a challenging process for many manufacturers and research people to produce plastic products meeting essential requirements in economical manner. The old concept of using the trial and error method to determine the process parameters for Injection Moulding Machine is no longer good enough. The difficulty of optimising an Injection Moulding Process is that the performance measures usually show conflicting behaviour. Therefore, a compromise must be found between all of the performance measures of interest. In this paper Injection Moulding process parameter optimisation for Low Density Polyethylene 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 optimised the process parameters.**

Key Words: Process parameter, Optimum value and Orthogonal Array etc.

I. INTRODUCTION

Injection Moulding is one of the most important shape forming processes for thermoplastic polymer. Maximum amount of all the plastic products are manufactured by Injection Moulding machine. Injection moulding machine is best suited for manufacturing large numbers of plastic products of complex structure and sizes. In the Injection Moulding 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 moulded plastic parts. Altan [2] optimized shrinkage of plastic material like Polypropylene and Polystyrene in Injection Moulding machine using Taguchi methodology. Altan 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 Moulding Machine for DVD manufacturing by optimising the parameter of Injection Moulding Machine. He optimised the process parameters like effective distance travel & speed, the cycle time while manufacturing DVD by Injection Moulding Machine in this way the quality of the product is improved and cycle time is also reduced. Similarly he found that the cooling time and holding time are also effective parameters to reduce cycle time. Alireza Akbarzadeh and Mohammad Sadeghi [4] applied the concept of ANOVA (Analysis of variance) 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 by conducting the various experiment finally he realised 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 mouldings using the Taguchi Optimisation Method. He realised on the shrinkage with three more defect characteristics like less weight, weld lines and sink marks. He was able to optimise many quality characteristics with very few experiments, which could lead to economical pattern. Mohd. Muktar Alam, Deepak Kumar [6] He determined method to minimise the shrinkage with the help of selection of optimal process parameter injection moulding 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 Moulding process. The Particle swarm Optimisation Algorithm (PSO) is analysed 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 to be used for a lot of practical applications. From the literature review, it can be concluded that in order to minimise such defects and to improve the productivity in plastic injection moulding processing condition, design of experiment by Taguchi Optimisation 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 minimise 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.

II. TAGUCHI'S METHODOLOGY

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, 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 is 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 analysing 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 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.

III. OPTIMISATION OF INJECTION MOULDING 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 mould cavity and subsequent solidification. Some important parameters of them are like Injection pressure, Injection speed, mould 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.

A. Selection of the definite value 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 mould 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 for conducting the experiments. Some set of definite values of all the process parameters are taken in the Table-1. 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 before starting of the experiment the selected values of the process parameters are well discussed with the Industry CIPET (Central Institute of Plastic Engineering and Technology, *Sonepat, Haryana, India*) personals.

S.NO.	Process Parameters	Unit	Level 1	Level 2	Level 3
1	Processing temperature	°C	130	150	170
2	Injection pressure	M Pa	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

B. Experimentation

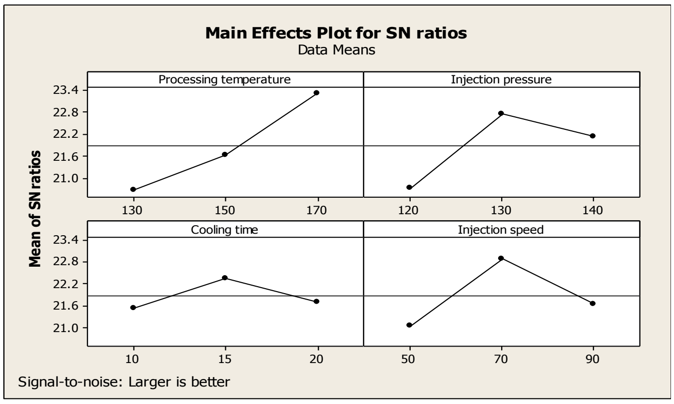
After selection of definite values of the process parameter L9 orthogonal array has been selected depending upon the total Degrees Of Freedom for the parameters. Plastic injection moulding experiments were carried out on a FERROMATIK MILACRON OMEGA 350 W Injection Moulding Machine.
Parameters are well discussed with the Industry and the CIPET (Central Institute of Plastic Engineering and Technology) Personals. For experimentation work the virgin LDPE (Low Density Polyethylene) material is used in a granules form.

Fig. 1: OMEGA 350 W Injection Moulding Machine

S. No.	A (P.T.)	B (I.P.)	C (C.T.)	D (I.S.)	T.S.	S/N ratio
1	130	120	10	50	8.33	23.18
2	130	130	15	70	14.33	11.63
3	130	140	20	90	11	14.47
4	150	120	15	90	11	20
5	150	130	20	50	12.33	15.45
6	150	140	10	70	13.67	23.52
7	170	120	20	70	14.33	23.52
8	170	130	10	90	15.33	22.46
9	170	140	15	50	14.67	22.08

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	20.66	20.72	21.55	21.07
2	21.63	22.76	22.37	22.90
3	23.32	22.14	21.70	21.65
Delta	2.66	2.04	0.82	1.83
Rank	1	2	4	3

Table-3: Response Table for S/N Ratio

C. CONCLUSIONS

The Taguchi methodology provides the optimum process parameter by taking different combinations of process parameters with the help of orthogonal array. The response table for 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 L.D.P.E. is A3, B2, C2, D2.The difference value given in table denotes which factor is the most significant for Tensile strength of L.D.P.E. Processing Temperature (A) is found most effective factor for L.D.P.E. followed by Injection Pressure (B), Injection speed (D) and cooling time (c).

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