Optimization of Process and Design Parameters of Plastic Injection Molding For Shrinkage Response using Taguchi and RSM Techniques

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Abstract— The present time is facing large consumption problem of conventional material like metals. High scale industrial development worldwide creates this problem from previous several decades. The only human made material called as plastic material provides some positive wave for this issue. But plastic material has various manufacturing issues which are highlighted by various engineering experts and resolve by researchers time to time research contributions. Dimensional shrinkage or volumetric shrinkage is general and commonest defect, occurred in PIM made products. The basic reason behind this defect is material mechanical and chemical properties as well as design and process parameters of required products. This research work is divided into two section of work. In first section of study process parameters are selected and then experimental work is completed. Five process parameters are select for this section of work which is following: mold temperature, melt temperature, injection pressure, packing pressure and cooling time. In second section design factors are selected which are following: number of gate system, gate size, runner size, and Sprue size and runner type.

Keywords— injection molding; taguchi method; grey relational analysis; warpage.

I.INTRODUCTION

In this research, Both studies are performed for common defect shrinkage and fill time of cavity. Experimental work is completed using PIM machine De-Tech 85 LNC5 made 2000. Test specimen is fabricated using family ,plastic (PP) and its selected is REPOL H110MA. The analysis of data compile for first section is based on Taguchi and regression modeling. So in this section signal to noise (S/N ratio) ratio analysis, rank identification and ANOVA analysis is performed. In second section same ANOVA analysis is performed and model equation is generated which is optimized using MOGA technique for both model equation generated by regression modeling. Computerized simulation techniques, such as computer aided design (CAD) and computer aided engineering (CAE) can be used to assist developers in analysis work that aims at predicting problems and their causes in the process of injection molding.. In this research, CAE software was used for mold flow analysis. Using the finite element method, the condition of the plastic in the mold cavity during various stages of the injection molding was simulated. The observations formed the basis for formulating essential settings for injection molding and parameters for mold design, with the aim of reducing the time and costs of product and mold development Currently, Among these, spare parts of locking devices require high precision, are complex in form, and often have warpage, welding line, air traps, and other defects in the finished product. Consequently, the selection and setting of the fabrication process parameters are crucial. In this research, a set of spare parts of an actual auto locking device is examined. Trial and error was used to determine the important parameters used in the actual production process. The quality of the product will decide if the parameter setting will be used or need to be changed; a process that is both time consuming and costly.

II.OBJECTIVE

Investigate the process and design parameter for ASTM test specimen (rectangular Bar) using taguchi and RSM techniques.

Experimental investigation of process parameters like mold temperature, melt temperature, injection pressure, packing pressure and cooling time on the performance measures like dimensional shrinkage and fill time are performed.

Numerical investigation of design parameters like gate number, gate size, runner size, and Sprue size and runner type on the performance measure like volumetric shrinkage and fill time are performed

Table 2.1 Common Molding Defects

Molding Defects	**Descriptions**	**Causes**
Sink Marks	Localized depression (In thicker zones)	Holding time /pressure too low, cooling time too short, with sprueless hot runners this can also be caused by the gate

Voids	Empty space within part (Air pocket)	Lack of Holding pressure (Holding pressure use to pack out the part during the holding time). Also mold may be out of registration (when
Weld line	Discolored line where two flow front meet	Mold/material temperature set to low (the material is cold when they meet ,so they don't bond)
Warping	Distorted part	Cooling is too short , material is too hot, lack of cooling around the tool, incorrect water temperatures (the part

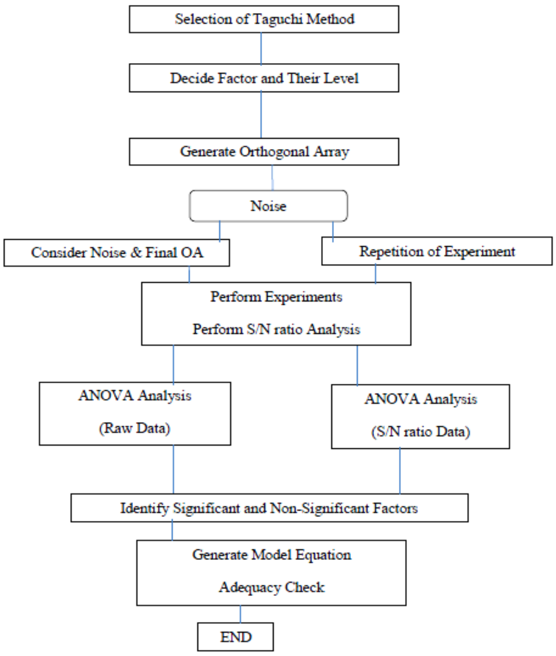

Figure 2.1 Work Flow Process Diagram

III. EXPERIMENTAL PARAMETERS

Table 3.1 Process Parameter for Practical

Factor	Parameter	Unit	Level		
			L1	L2	L3
A	Mold Temperature	C	40	50	60
B	Melt Temperature	C	205	215	225
C	Injection Pressure	Bar	40	50	60
D	Packing Pressure	%	80	85	90
E	Cooling Time	Sec	5	10	15

Table 3.2 Design Parameter for Practical

Coded Factors	Coded Factors	Unit	Level		
			-1	0	+1
D*	No of Gate	NA	2	4	-
D1	Gate Size	mm	8	10	12
D2	Runner Size	mm	5	7	9
D3	Sprue Size	mm	5	6	7
D4	Runner Type	NA	1	2	3

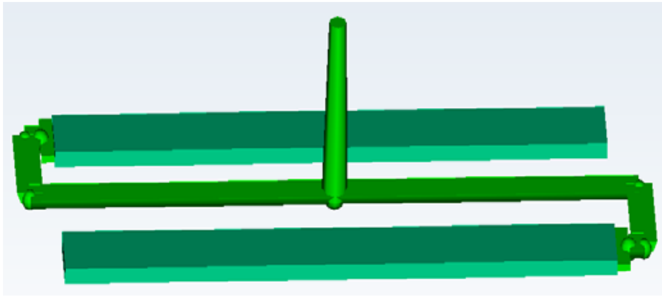

Figure: 3.1 CAE MODEL FOR SIMULATION

IV. RESULT OF CAE MODEL SIMULATION

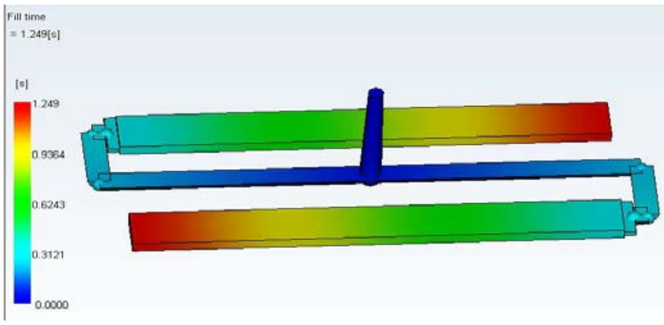

Figure 4.1 Fill Time required for test product

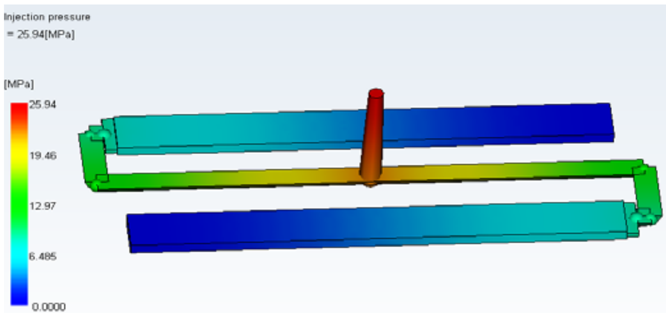

Figure 4.2 Injection Pressure required for test product

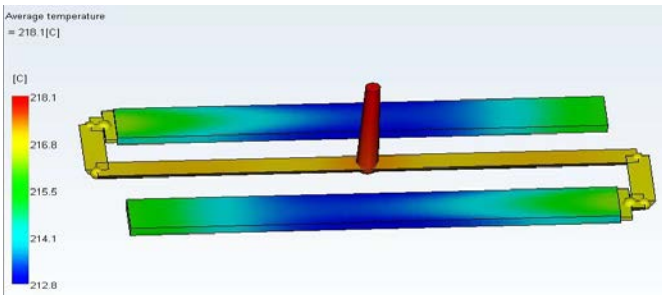

Figure 4.3 Temperature during injection process for test product

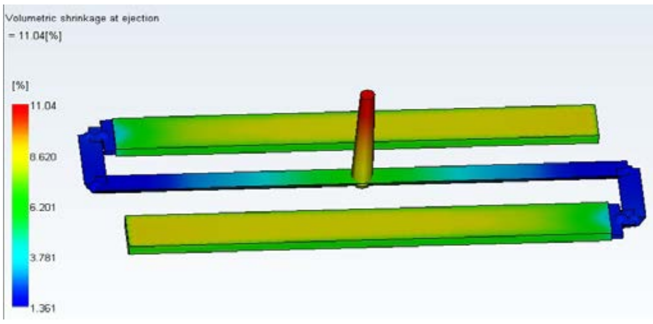

Figure 4.4 Shrinkage during injection process for test product

V. RESPONSE TABLE FOR MEAN VALUES FOR CASE STUDY I

Table 5.1 Process Real values for Practical

Level	Mold Temp	Melt Temp	Inj. Press	Pack Press	Cool Time
1	2.125	2.360	2.653	3.209	2.296
2	3.012	2.900	2.919	2.906	2.938
3	3.611	3.488	3.176	2.632	3.513
Delta	1.487	1.128	0.523	0.577	1.218
Rank	1	3	5	4	2

Table 5.2 Shrinkage values for Process Pararmeter

No. of Exp.	Ex_Shrinkage	Vol Sh (Ex)	Vol Sh (Simulation)	Error	S/N Ratio Value
1	1.08	8.51	10.51	19.03	-0.67
2	1.74	8.99	10.99	18.20	-4.80
3	1.98	9.16	10.16	9.84	-5.93
4	1.69	8.96	10.96	18.25	-4.58
5	2.04	9.21	11.21	17.84	-6.19

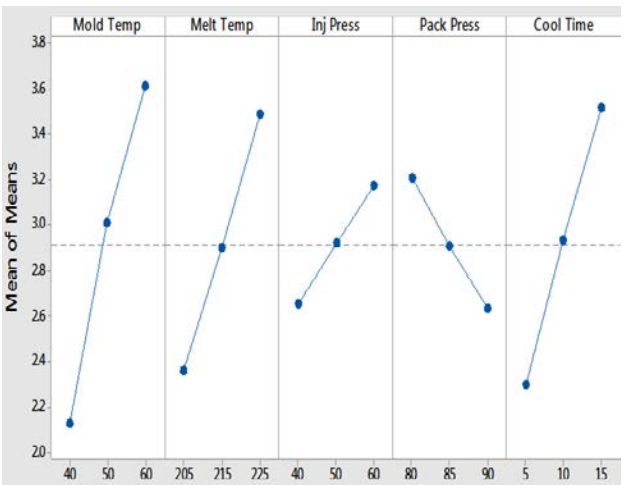

Figure 5.1 Mean ratio plot for Case study I Table 5.3 ANOVA analysis for case study I

Source	DF	Adj. SS	Adj. MS	F-value	P-value
Regression	5	25.0771	5.0154	233.93	0.00
Mold Temp	1	9.9469	9.9469	463.94	0.00
Melt Temp	1	5.7278	5.7278	267.16	0.00
Inj. Press	1	1.2320	1.2320	57.46	0.00
Pack Press	1	1.5000	1.4900	69.96	0.00
Cool Time	1	6.6704	6.6704	311.12	0.00
Error	21	0.4502	0.0214		
Total	26	25.527			

Table 5.5 Model Summary for case study I

S	R^2	R^2 (Adj.)	R^2 (Pred)
0.1464	98.24	97.82	96.91

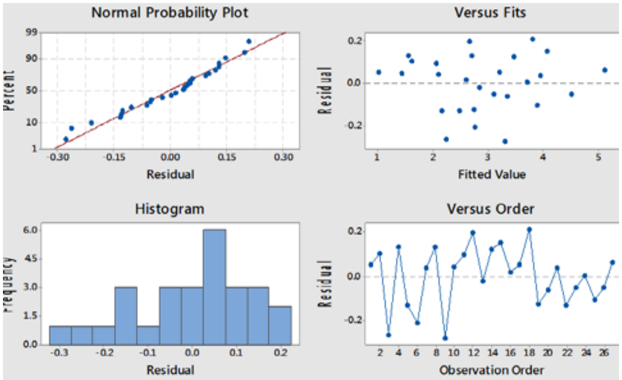

Figure 5.2 Residual plots for Case Study I for Sh value

VI. Experiment Table for case study II for Vol. Shrinkage Table 6.1 Experiment Table for case study II for Vol. Shrinkage

Table 5.4: Best cases for case study I

Best Case (S/N ratio) for Case Study					
	Mold Temp	Melt Temp	Inj. Press	Pack Press	Cool Time
Value	40	205	40	90	5
Best Case (Mean) for Case Study					
	Mold Temp	Melt Temp	Inj. Press	Pack Press	Cool Time
Value	40	205	40	90	5

Run Order	D1	D2	D3	D4	D*	Vol Sh.	S/N Ratio
1	10	5	6	1	4	10.91	-20.75
2	10	7	5	1	4	10.89	-20.74
3	12	7	5	2	4	11.47	-21.19
4	10	7	5	3	4	11.78	-21.42
5	10	7	7	3	4	12.38	-21.86

Regression Equation

Ex_Shrinkage = -10.547 + 0.07434 Mold Temp + 0.05641 Melt Temp

+ 0.02616 Inj. Press

- 0.05773 Pack Press + 0.12175 Cool Time

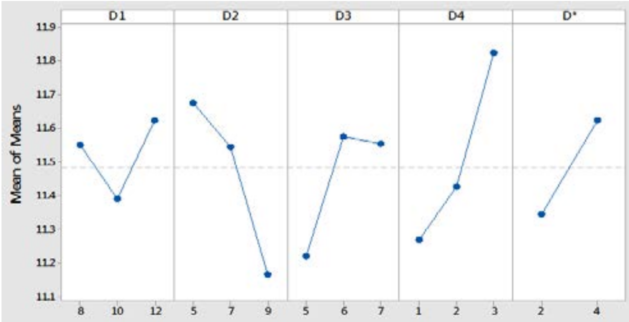

Figure 6.1 Mean analysis plots for Case Study II

ANOVA Analysis (Case-II)

In this non-linear regression modeling is analysis and significance of design variable is present for generated model equation using ANOVA analysis. ANOVA table for case-II is present in table 5.12 for linear, square and 2-way model equations.

Sour ce	D F	Seq SS	Contribu tion	Adj. SS	Adj. MS	F-Value	P-Value
Mod el	19	10.6014	97.03%	10.6014	0.55797	58.55	0.000
Line ar	5	5.1888	47.49%	5.1888	1.03775	108.90	0.000
D1	1	0.0302	0.28%	0.0302	0.03020	3.17	0.084
D2	1	1.5790	14.45%	1.5790	1.57899	165.70	0.000
D3	1	0.6691	6.12%	0.6691	0.66907	70.21	0.000
D4	1	1.8687	17.10%	1.8687	1.86869	196.10	0.000
D*	1	1.0418	9.54%	1.0418	1.04179	109.33	0.000

Table 6.3 ANOVA analysis for case study II

VII. OPTIMIZATION OF RESPONSE VARIABLE FOR BOTH CASES (GENETIC ALGORITHM)

Case-I (Optimal shrinkage 0.469 at process parameters values A (Mold Temperature) 40 C,

B (Melt Temperature) 205 C, C (Injection Pressure) 40 Mpa D (packing Pressure) 36 MPa E (Cooling Time) 5 Sec

Case-II (Optimal Volumetric Shrinkage 4.84 at design parameters values D* (No of Gate) 2

D1 (Gate Size) 9 mm D2 (Runner Size) 7 mm D3 (Sprue Size) 3 mm D4 (Runner Type) 3

Regression Equation

Vol Sh = 13.59 - 1.173 D1 + 0.635 D2 + 1.206 D3 - 1.115 D4 - 1.075 D*

+ 0.04045 D1*D1

- 0.02219 D2*D2 - 0.1397 D3*D3 + 0.1004 D4*D4 - 0.01029 D1*D2

+ 0.0135 D1*D3

+ 0.0989 D1*D4 + 0.05846 D1*D* + 0.0283 D2*D3 - 0.1772 D2*D4 -

0.05510 D2*D* + 0.0530 D3*D4 + 0.0662 D3*D* + 0.3087 D4*D*

Table 6.4 Model Summary for case study II

S	R-sq	R-sq(adj.)	Press	R-sq(Pred.)
0.0976173	97.03%	95.38%	0.868289	92.05%

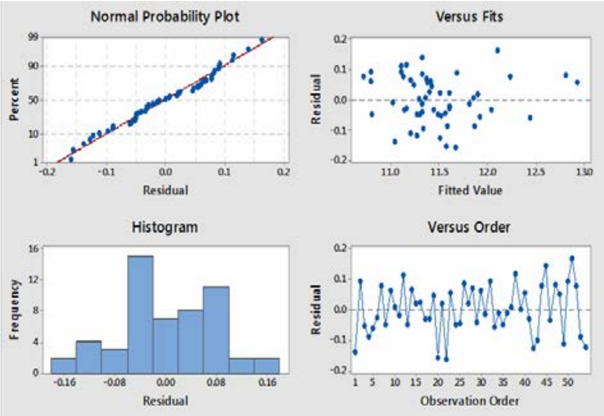

Figure 6.2 Residual Plots for case study II for Vol Sh

VIII. FUTURE SCOPE

In this case, of study, mathematical modeling and optimization of process parameters has made for dimensional shrinkage. The work can be enhancing to pursue more response variables like war page, surface roughness, mechanical properties etc. Also, more process parameters such as injection velocity, packing pressure, packing time, holding time, holding pressure, etc. can be introduce to have a better insight in to the process. The same research methodology can be applied on other materials also.

IX. REFERENCES

[1]. 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.

[2]. A.O.Andrisano, F.Gherardini, F.Leali, M.Pellicciari and A.Vergnano, Design of Simulation Experiments method for Injection Moulding process optimization‖, International conference on Innovative Methods in Product Design, Venice, Italy, June 2011.

[3]. Mahmoud A. Barghash and Faisal Alkhannan Alkaabneh, ―Shrinkage and Warpage Detailed Analysis and Optimization for the Injection Molding Process Using Multistage Experimental Design‖, Quality Engineering, 26:319–334, 2014.

[4]. B. Berginc, Z. Kampus and B. Sustarsic, The use of the Taguchi approach to determine the influence of injection-moulding parameters on the properties of green parts‖, Journal of achievements in material and manufacturing engineering. Volume 15, March- April 2006.

[5]. E. Bociga and T. Jaruga, ―Experimental investigation of polymer flow in injection mould‖, Archives of Materials Science and Engineering, Volume 28 Issue 3 Pages 165-172, March 2007.

[6]. Shen Changyu, Wang Lixia and Li Qian, Optimization of injection molding process parameters using combination of artificial neural network and genetic algorithm method‖, Journal of Materials Processing Technology 183, 412–418, 2007.

[7]. Pitchakorn Chavanatnusorn, Determination of the Optimal Processing Conditions in Plastic Injection Molding Using Computer-aided Engineering, Artificial Neural Network Model, and Genetic Algorithm‖, Graduate School, Kasetsart University, 2009.

[8]. Chih-Cherng Chen, Pao-Lin Su, Chung-Biau Chiou and Ko-Ta Chiang, Experimental Investigation of Designed Parameters on Dimension Shrinkage of Injection Molded Thin-Wall Part by Integrated Response Surface Methodology and Genetic Algorithm: A Case Study‖, Materials and Manufacturing Processes, 26: 534–540, 2011.

[9]. Ming-Tsan Chuang, Yung-Kuang Yang and Yun-Hsiang Hsiao, Modeling and Optimization of Injection Molding Process Parameters for Thin-Shell Plastic Parts‖, Polymer-Plastics Technology and Engineering, 48: 745–753, 2009.