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Analysis of Warpage in Injection Molded Parts via Taguchi Method

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ABSTRACT
Injection molding is a process for forming parts by molding material into a desired shape. In this paper, we have characterized four inputs according to which the final warpage (residual stresses) of the material varies. Those four inputs are injection pressure, injection temperature, cooling time, and holding pressure. In all these we already know that Injection Pressure has the most contribution in the final geometry. So, from the values Library we take a set of four possible values of each parameter and make an orthogonal array of that for Taguchi analysis. After testing all the possible combinations in ANOVA, we conclude the final set of parameters which give the minimum S/N ratio or minimum warpage.

Keywords: cooling time, holding pressure, injection pressure, injection temperature, warpage

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INTRODUCTION

Injection molding is a gathering system for conveying parts by implanting material into a shape. Infusion trim can be performed with a vast gathering of materials, including metals, (for which the system is called diecasting), glasses, elastomers, desserts, and most normally thermoplastic and thermosetting polymers. Material for the part is reinforced into a warmed barrel, mixed, and obliged into a shape pit, where it cools and hardens to the setup of the hole. After a thing is created, commonly by a mechanical fashioner or a pro, molds are made by a mould maker (or toolmaker) from metal, when in doubt either steel or aluminum, and precision machined to shape the components of the pined for part. Infusion trim is by and large used for collecting a grouping of parts, from the tiniest fragments to entire body sheets of cars. Pushes in 3D printing advancement, using photopolymers which don't melt during the infusion trim of some lower temperature thermoplastics, can be used for some direct infusion molds.

Material for the part is energized into a warmed barrel, mixed, and compelled into a shape gap, where it cools and hardens to the course of action of the cavity. After a thing is created, when in doubt by a mechanical originator or a planner, molds are made by a form producer (or toolmaker) from metal, as a general rule either steel or aluminum, and precision machined to outline the components of the pined for part.

This process is majorly used in making the components, automotive components, cable assemblies, electronics, electronic components, etc.

In this paper we have applied Taguchi's method to find residual stresses the material is under based on 4 input characteristics: injection pressure, injection temperature, cooling time and holding pressure.

Past Work

Shi et al [1] has pointed on a half and half system in a delicate registering worldview for the improvement (diminishment in remaining stress) of the plastic infusion forming process. The half and half technique consolidates numerical reenactment programming, a hereditary calculation and a multilayer neural system to improve the procedure parameters. An inexact investigation model is produced utilizing a Back-engendering neural system with a specific end goal to maintain a strategic distance from the costly calculation coming about because of the numerical recreation programming. It is demonstrated that there is a connection between shear stress amid filling and leftover stress in the part, i.e. the nature of the part. The final parameters are P_{inj} (Mpa)=55, T_{melt} (℃)= 260, T_{inj}(sec)=2.

Ozcelik et al [2] means to accomplish the base warpage, the suitable procedure condition parameters are resolved. Form temperature, soften temperature, pressing weight, pressing time, runner sort, entryway area and cooling time are considered as process condition parameters. The most basic process parameters affecting warpage are resolved utilizing limited component investigation comes about in light of examination of fluctuation strategy. ANOVA shows that pressing weight, shape temperature, soften temperature, pressing time, cooling time, runner sort and door area impact warpage by 33.6, 21.5, 20.6, 16.2, 5.2, 1.4 and 1.4%, respectively.

Uzman et al [3] has aimed on finding the respective percentages by which different parameters affect the warpage. For this purpose, right off the bat, L27 orthogonal array was made for 27 limited component (FE) investigations of orthose part by using five process parameters, for example, material stream rate (MFR), infusion speed (Iv), form temperature (MoT), and soften temperature (MeT) comparing to infusion time (It) parameter. Besides, L9 orthogonal was made for 9 limited component (FE) examinations of every one of those part by utilizing four process parameters including infusion time (It), pressing weight (PP), pressing weight time (PPT), and cooling time (CT) comparing to warpage and shrinkage parameters. The net rates were Packing pressure(Pp) =58.03%, Packing weight time(PPT)=23.03%, Injection time(IT)=15.17 Cooling time(CT)=3.68%.

Dearnley et al [4] has aimed in reducing the surface friction in order to reduce the wear and energy consumption. He has done this by using many different materials and combination of materials. The process used was magnetron sputtering technique at 200℃, and the coatings were TiN, CrN and MoS, some other metals were spark eroded and the surface roughness was tested in axial as well as tangential direction. From the rubbed dies, the highest friction force was of TiNr polished P20 but the lowest friction force was noticed for CrNrpolished P20n.

Chen et al [5] has used two methods, which is applying the L25 OA on 6 control factors (melting temperature, injection speed, injecting pressure, VP switch, holding pressure and packing duration) and the second via the integration of Taguchi and soft computing, termed as the ‘proposed approach’. By both the approaches the optimal values with the high S/N ratio were determined, and the results were compared. It was found that the proposed approach had more effective results and higher S/N ratios.

Tang et al [6] studied 4 mold designs and performed various tests, such as thermal residual stress analysis and tensile test, on them to determine in which type of mold the defects are minimum. The defects included flashing, short shot, and warpage. It was found the design having extra air vents in the cavity corners, had least short shot, as it allowed trapped air to escape. The phenomenon of Flashing was decreased by reducing the holding pressure of the machine. By controlling injection temperature, injection time, and melting temperature, warpage can be controlled.

Altan et al [7] determined the amount of shrinkage taking place during injection molding of polypropylene (PP) and polystyrene (PS) semi crystalline polymers, via L27 OA. The control parameters were injection pressure, melt temperature, packing time and packing pressure which were varied at 3 levels. The observations depicted that 260°C of melting temp, 50 Mega Pascal of packing pressure and 15 seconds of packing time showed least shrinkages of 0.936% (PP) and 1.223% (PS).

Kamaruddin et al [8] has aimed to implement Taguchi method for finding optimal functional variables that affect the bending realization of the plastic to be made. As per experimentation, a main effect, signal-to-noise (S/N) ratio, an orthogonal array (OA), and analysis of variance (ANOVA) were employed to investigate the bending characteristics of the tray under a constant load. The by-product, in terms of average bending deflection were obtained after conducting the bending experiment for all nine patterns. The final parameters obtained were melting temperature – 200°C, injection speed – 261 rpm, cooling time – 15 sec, and holding pressure – 827 kPa.

EXPERIMENTAL WORK

The variables were identified to develop mathematical models to predict solely and mingled effects of the parameters. The various parameters selected were:

- Melting temp
- Injection pressure

Taguchi's design was the basis of the flow of the experiment. This method is based on orthogonal arrays and helps determine the optimal settings in which to conduct the experiment.

Orthogonal arrays assist in providing a minimum number of experiments and also the signal-to-noise ratio (S/N ratio) which are the log function of the desired output, this helps in analyzing data and for the prediction of optimum results.

The 3 S/N ratios for optimization are (n being the MSNR):

(i) Smaller the better
(ii) n = - 10 $\log_{10}$ (mean sum of squares)
(iii)Larger the better
(iv)n = - 10 $\log_{10}$ (reciprocal of the mean sum of squares)
(v) Nominal is best
(vi)n = - 10 $\log_{10}$ (mean sum of squares/variance)

By applying Taguchi method to this, we get the shrinkage % and average deflection values for each of the following input parameters. With the help of average deflection and shrinkage % we are able to easily calculate the warpage (%), at the optimum values.

RESULTS AND DISCUSSION

The ranking shown in the Table 1 shows the relative contribution of the factors on multiple quality characteristics.

For average bending deflection, the calculations for the S/N ratio have been done based on 'Larger the Better' model. From this it shows that the holding pressure (kPa) has the most effect on the average bending deflection.

The graphical representation of factor effect on the quality characteristic at different levels is shown in Figure 1.

Table 1. *Relative contribution of the factors on multiple quality characteristics.*

			Cooling holding	
Level	**Melting temp (°C)**	**Injection speed (RPM)**	**Time (sec)**	**Pressure (kPa)**
1	6.562	6.326	6.131	5.786
2	6.235	6.225	6.771	6.162
3	6.479	6.725	6.373	7.328
Delta	0.327	0.500	0.640	1.542
Rank	4	3	2	1

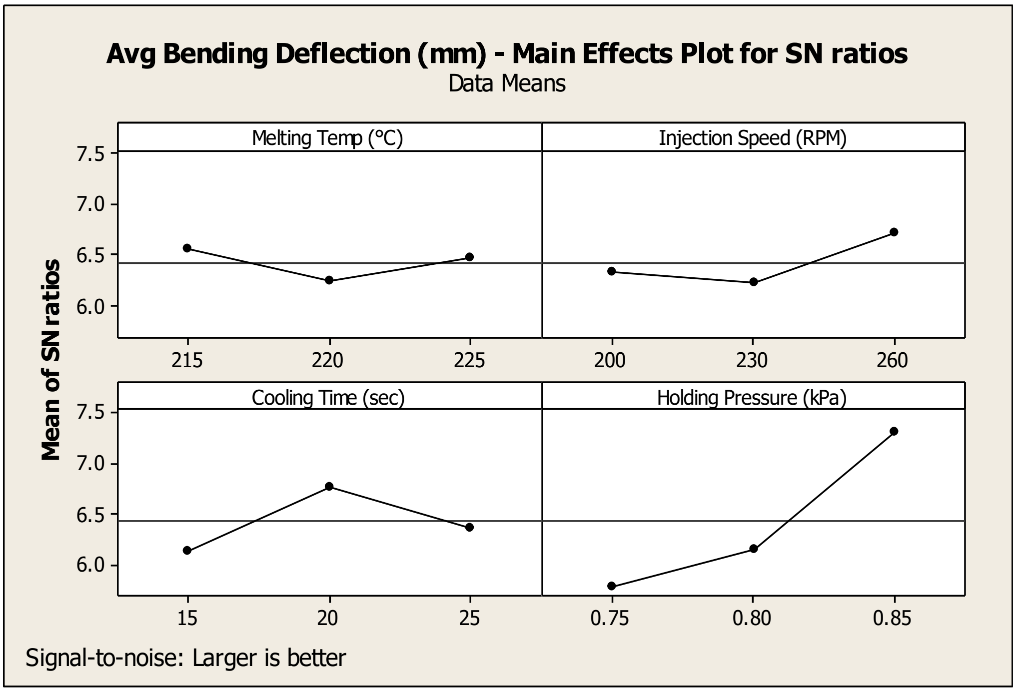

Fig. 1. *Factor effect on the quality characteristic at different levels.*

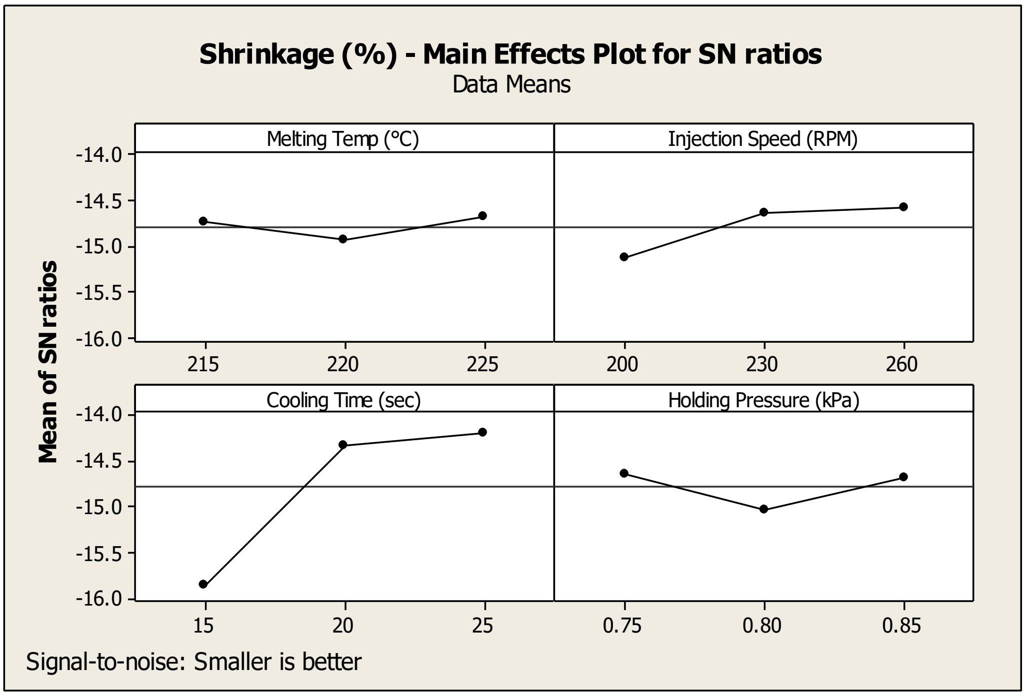

Fig. 2. *Calculations for S/N ratio for shrinkage %.*

The optimum levels of different control factors for it obtained are melting temperature at level 1 (215°C), injection speed at level 3 (260 RPM), cooling time at level 2 (20 sec) and holding pressure at level 3 (0.85 kPa).

Similarly, the calculations for S/N ratio for shrinkage %, is based on the 'Smaller the Better' model (Figure 2).

Thus, the optimum levels for each parameter are at level 3, level 3 and level 1 form each input parameter respectively.
(diagram in yellow to be inserted here)
With the optimum parameter values for each we are able to calculate the warpage in %.

A confirmation test was performed for the same and the deviation of the experimental value from the calculated value was found to be within 5%. Thus, proving the process is optimized[9-12].

Process parameters	Melting temperature (℃)	Injection speed (mm/min)	Cooling time (sec)	Holding pressure (MPa)	Average bending deflection (mm)	Warpage (%)
Level values	215	260	25	0.85	2.43	4.909

Quality characteristics	Optimal setting of parameters	Predicted and confirmation results		
		Predicted optimal values of quality characteristics	Experimental values of quality characteristics	% Error
Warpage (%)	A2B3C3D3	5.121	4.909	4.32

Exp no.	Melting temp (°C)	Injection speed (RPM)	Cooling time (sec)	Holding pressure (MPa)	Average bending deflection (mm)	Shrinkage (%)
1	215	200	15	0.75	1.89	6.301
2	215	230	20	0.80	2.10	5.239
3	215	260	25	0.85	2.43	4.909
4	220	200	20	0.85	2.34	5.441
5	220	230	25	0.75	1.85	5.030
6	220	260	15	0.80	1.99	6.350
7	225	200	25	0.80	2.01	5.411
8	225	230	15	0.85	2.21	5.959
9	225	260	20	0.75	2.11	4.941

CONCLUSION

The impacts of the physical parameters were examined and the conclusion was:

(1) Taguchi enhancement strategy was connected to locate the ideal procedure parameters for a wide range of surfaces for least warpage. A Taguchi orthogonal cluster, the sound to noise (S/N) proportion and examination of change were utilized for the improvement of the parameters. An affirmation analysis was additionally led and confirmed for the adequacy of the Taguchi advancement technique.

(2) The examination esteem that is seen from ideal parameters; are Pinj (Kpa)=85, Tmelt(℃)= 260, Tinj(sec)=25.

(3) The warpage is less in more infusion weight handle. In this manner, this procedure gives a superior surface smoothness.

REFERENCES

[1] F. Shi, Z.L. Lou, J.G. Lu, Y.Q. Zhang. Optimization of plastic injection molding process with soft computing, *Int J Adv Manuf Technol*. 2003; 21: 656–61p.

[2] B. Ozcelik, T. Erzurumlu. Comparison of the warpage optimization in the plastic injection

molding using ANOVA, neural network model and genetic algorithm, *J Mater Process Technol*. 2006; 171: 437–45p.

[3] H. Oktem, T. Erzurumlu, I. Uzman. Application of Taguchi optimization technique in determining plastic injection molding process parameters for a thin-shell part, *Mater Des*. 2007; 28: 1271–8p.

[4] P.A. Dearnley. Low friction surfaces for plastic injection moulding dies an experimental case study, *Wear*. 1999; 225–229: 1109–13p

[5] W.-C. Chen, G.-L. Fu, P.-H. Tai, W.-J. Deng. Process parameter optimization for MIMO plastic injection molding via soft computing, *Expert Syst Appl*. 2009; 36: 1114–22p.

[6] S.H. Tang, Y.M. Kong, S.M. Sapuan, R. Samin, S. Sulaiman. Design and thermal analysis of plastic injection mould, *J Mater Process Technol*. 2006; 171: 259–67p

[7] M. Altan. Reducing shrinkage in injection moldings via the Taguchi, ANOVA and neural network methods, *Mater Des*. 2010; 31: 599–604p.

[8] S. Kamaruddin, Z.A. Khan, K.S. Wan. The use of the taguchi method in determining the optimum plastic injection moulding parameters for the production of a consumer product, *J Mekanikal Disember*. 2004; 18: 98–110p.

[9] D. Mathivanan, M. Nouby, R. Vidhya. Minimization of sink mark defects in injection molding process Taguchi approach, *Int J Eng Sci Technol*. 2010; 2(2): 13–22p.

[10] M. Kurt, Y. Kaynak, O.S. Kamber, B. Mutlu, B. Bakir, U. Koklu. Influence of molding conditions on the shrinkage and roundness of injection molded parts, *Int J Adv ManufTechnol*. 2010; 46: 571–8p.

[11] W. He, Y.F. Zhang, K.S. Lee, J.Y.H. Fuh, A.Y.C. Nee. Automated process parameter resetting for injection moulding: a fuzzy-neuro approach, *J Intell Manuf*. 1998; 9: 17–27p.

[12] M. Zhai, Y.C. Lam, Æ.C.K. Au. Runner sizing and weld line positioning for plastics injection moulding with multiple gates, *Eng Comput*. 2006; 21: 218–24p.