Study and optimization of effective parameters in the occurrence of Blush defect in the plastic injection molding process by analysis of variance

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ABSTRACT

Plastic injection is one of the most important and common processes in plastic parts production. During this process, many defects can take place that affect products quality. So trying to remove this defects is very vital for the plastic industry. This research focuses on removing or decreasing one of these defects, called Blush. For this purpose, eight parameters with the probability of affecting the occurrence of this defect, which are material temperature, injection speed, mold temperature, holding pressure, runner diameter, gate diameter, gate angle, and included angle have been considered to be investigated. To study the effect or lack of effect, the extent, and the manner of effect of these parameters on the Blush defect, a 1/8 Fractional factorial design of experiment with eight factors and two levels was performed by Minitab software. Then after finite element analysis in MoldFlow software and validation of analysis with experimental tests, the area of defect that occurred in each case was calculated by geometric methods. After ANOVA of the data, it was found that the parameters of runner diameter, holding pressure, flow rate, and melt temperature respectively, have the most significant effects on this defect. Then, for the four factors mentioned, an experimental design of Composite Cube Design (CCD) was performed and after performing finite element analysis and analysis of variance on the data, it was found that all four parameters have a significant impact. It was also found that by increasing melt temperature, and holding pressure and reducing the runner diameter and flow rate to the optimal level, the area of blush defect will be reduced by 82.2%.

KEYWORDS

FEA, plastic injection molding, optimization, Blush defect, ANOVA

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Introduction

Llado et al. [1] researched on the effect of process parameters of Blush defect. After studies it became clear that the most important factors are flow rate and Melt temp respectively. Kitayama et al. [2] conducted a multi-objective optimization using a RBF and pareto solution to improve cycle time and warpage at the same time. Another study was conducted by li et al. [3] assuming warpage, shrinkage and residual stress as the key factors of part quality. They used taguchi method, RSM and genetic algorithm to optimize this problem. Guo et al. [4] tried to improve the warpage a micro-cellular foam injected part. They used FEA, back propagation neural network, combination of GA and ANN and combination of PSO and ANN for this purpose. After optimizations the value of warpage decreased significantly by exertion of optimized input parameters levels. In a different study, Kitayama et al. [5] tried to improve weld lines by means of rising the melt front temperature. Other objective of this study was reduction of clamping force. They used RBF method to access the Pareto-Frontier solution and choose an acceptable level for both parameters. Martowibowo et al. [6] used FEA method and genetic algorithm to reduce the cycle time. Also they could develop a model that predicts results with just 1% of error. Other study by li et al. [7] was conducted to decrease the production cost, and increase the quality and efficiency. They used GA and GKriging method to get access to pareto-frontier solution. Their developed method predicted the results with less than 2% of error. In this study eight parameters of melt temperature, mold temperature, holding pressure, flow rate, runner diameter, gate diameter, gate angle and included angle were considered to evaluate their effect on the area of blush defect using DOE, FEA and NOVA. The innovation of this work is considering numerous design parameters to have a better view of effective parameters and also considering interaction effects of two parameters.

Theory

At first, the CAD model was created using CATIA software, and was meshed by means of MOLDFLOW. After creating the mold geometry and setting up the process parameters, the analysis was started. The steps of initializing the model are shown in figure1.

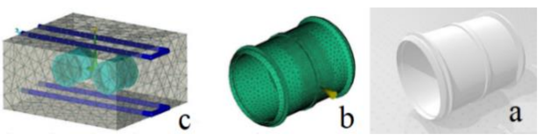

Fig1. a)part geometry b)meshed part c)mold geometry including runners and cooling channels

The material used in this study is Benvic IR705 manufactured by Solvay ET CIE Belgium. Two design of experiments were carried out using MINITAB software. The first one was a 2-level DOE with 8 parameters and the second one was performed with 5 levels and 4 parameters that identified as effective parameters in firs DOE. The levels of this designs are shown in Table1 and Table2.

Table1. Parameters levels for simulation analysis

	Up	Low
Melt T °C	185	195
Mold T °C	25	35
Flow rate g/cm3	15	25
Holding P Mpa	60	80
Runner D mm	7	10
Gate D mm	2.5	4.5
Gate Angle °	0	45
Included Angle °	25	45

Table2. Secondary DOE by Central Composite Design

No.	Melt (°C) Temp	Flow Rate (g/cm^3)	Holding Pressure (MPa)	Runner Diameter(mm)
1	185.2	12	54.6	6.4
2	187	14	59	7
3	191	19	70	8.5
4	196	24	81	10
5	197.8	26	85.4	10.6

After FEA, the area of defect should be measured using some Trigonometric relations. As the shape of blush defect is often similar to an ellipse, the relations used to calculate the area defect is actually the formula of calculating the area of ellipse. Fig2 shows the defect area.

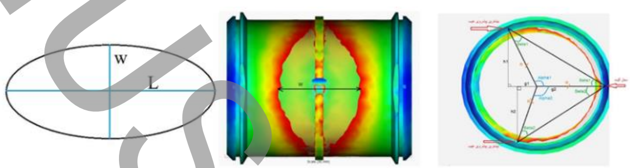

Fig2. Pictures of defect, showing W,L,Alpha1,Alpha2, and R

Results and discussion

After validation of the analysis, the FEA analyzes suggested by DOE were carried out and the results were included in ANOVA. It was revealed that the most important factors affecting Blush defect are runner diameter, holding pressure, flow rate and melt temperature respectively. The main effects plot is shown in fig3.

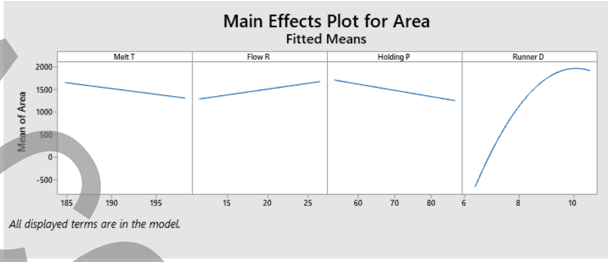

Fig3. Effect of the four effective parameters on the area of defect

Also the below regression equation was suggested to predict the area of Blush.

$$Area = -12367-25.4A+25.7B-13.82C+3898D-193.2D \quad (1)$$

After optimization of design parameters levels, the amounts of 6.71mm, 56.4MPa, 26cm^3/s, and 197.75℃ were suggested for runner diameter, holding pressure, flow rate and melt temperature respectively to minimize the area of blush. After employing these optimal levels in FEA, the area of defect was reduced to 82.2% less than what was before optimization. The table3 and fig4 show these results.

Table3. Comparison of Blush defect before and after the optimization

Title	Melt T (℃)	Flow rate (g/s)	Holding P (MPa)	Runner D (mm)	Defect Area
Initial part	197	12	35	10	1978
Optimal part in FEA	197.7	26	54.6	6.7	351

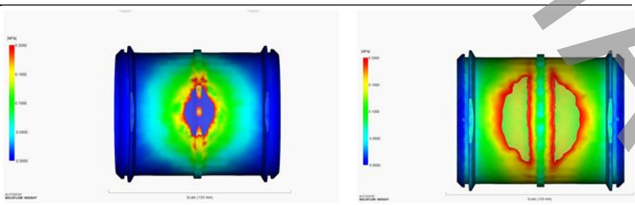

Fig4. Pictures related to before (right hand side) and after (Left hand side) the optimization

Conclusions

The results of this study are as follows:

- It was revealed from the first DOE that parameters of mold temperature, gate diameter, included angle and gate angle have negligible effect on results
- After second DOE and analysis of variances, the parameters of runner diameter, holding pressure, flow rate and melt temperature identified as the most effective parameters respectively.
- The results showed that blush defect area has a direct relation with the runner diameter and flow rate and a reverse relation with melt temperature and holding pressure.
- After optimizations, the area of defect experienced an 82.2% decrease.

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