Cycle Time Reduction for Optimization Of Injection Molding Machine Parameters for Process Improvement

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Abstract

Injection molding is a worldwide business that companies around the world use as a predominant method in manufacturing. Optimizing the parameters of the injection molding machine is critical to improve manufacturing processes. This research focuses on the optimization of injection molding machine parameters using one material. Suggestions for process improvements are made based on the results of a designed experiment.

The objective of this experiment is to provide statistical evidence for optimizing parameters of an injection molding machine. The machine parameters to be investigated include cooling time, back pressure, and plasticizing limit. These parameters are evaluated against the problem of decreasing the cycle time for each part. Experimental data were collected following the designed experiment procedures, and a statistical analysis was performed to give a basis for process improvement recommendations.

The results of the experiment showed a way to achieve the goal of optimizing the injection molding machine in a sensible and cost efficient way. Results presented in this paper will have a broader impact on the process of injection molding when trying to use more than one material.

Introduction

Injection molding is an industrial technology first used in the 1920's. From this date, many companies have adopted this technology using it from automotive parts to everyday items such as a plastic fork. Companies that use injection molding machines will have a need for optimizing the machine to decrease cycle time and increase profits. Having a process that is efficient is necessary in this world market to compete with world class companies. Cutting down the cycle time for each part is a major concern with the injection molding machine.

This research is to design an experiment to optimize an injection molding machine by manipulating parameters to reduce cycle time and to recommend further improvements of the process. Our specific objectives of this research are set as follows:

- Manipulate cooling time, back pressure, and plasticizing limit on the injection molding machine to reduce the cycle time and keep the quality of the part that deal with problems such as shrinkage, flash, and other abnormalities.

- Provide statistical evidence for optimizing parameters of an injection molding machine.
- A statistical analysis will be performed to give a basis for process and quality improvement recommendations.

Experimental Setup and Procedures

The experiment was conducted using a designed procedure dealing with polypropylene to optimize an injection molding machine by manipulating parameters to reduce cycle time and to recommend further improvements. The controls were first familiarized with the injection molder controls. This consisted of being able to locate and manipulate the three parameters, which include back pressure, cooling time, and shot size. The heater band's temperatures on the injection molding machine were held constant. By manipulating these parameters, the experiment should reveal significant parameters.

The design matrix was setup to record the cycle time for each run. The runs were randomized using the random function in Excel. The parameters were set using a two level factorial design giving each parameter a high and low value. The high and low levels for cooling time was 5 and 15 seconds, plasticizing limit was 70 and 88 mm, and back pressure was set at 5 and 17 bar. Three replications were done for each run and the cycle times were recorded for each part. Each part was also examined visually for abnormalities which include shrinkage, flash, and incomplete parts.

After the cycle times were recorded, the data was inserted into Microsoft Excel Software and Mini Tab Software. The data was statistically analyzed using a 2^3 level factorial design. Dummy code was inserted into the matrix to mathematically manipulate the raw data into the matrix. Each run was averaged and the procedure to statistically analyze the data was conducted.

To analyze the data, an analysis of variance table or ANOVA table was used to compare each parameter. This will tell what parameters are significant to the experiment and if any parameters had any interactions with each other. The f-statistic was compared to the f-critical value. If the f-statistic value is larger than the f-critical, the parameter has a statistical significance. The p-value is also important to look at because it states the probability of wrongly throwing out the null hypothesis.

Experimental Results and Analysis

Table 1 shows the design and raw data collected through the experiment. Parameters A, B, and C represent Cooling Time (sec.), Plasticizing Limit, and Back Pressure (bar), respectively. There were three replications of each run and the cycle times were averaged. When the runs for the experiment were recorded, a statistical analysis was done to conclude evidence on the data that there were some main effects and interactions.

Table 1 Design Parameters and Experimental Data

Run #		A	B	C		Runs	Quality
1	[1]	5	70	5	22	23	Good
2	a	15	70	5	7	16.06	Bad
3	b	5	88	5	21	22.25	Good
4	c	5	70	17	24	22.72	Bad
5	ab	15	88	5	16	22.91	Bad
6	ac	15	70	17	20	16.72	Good
7	bc	5	88	17	12	16.5	Good
8	abc	15	88	17	14	22.69	Good
9	[1]	5	70	5	8	22.44	Good
10	a	15	70	5	3	22.28	Good
11	b	5	88	5	2	22.18	Bad
12	c	5	70	17	13	22.08	Good
13	ab	15	88	5	9	12.69	Good
14	ac	15	70	17	11	13.63	Bad
15	bc	5	88	17	19	13.4	Bad
16	abc	15	88	17	23	16.72	Bad
17	[1]	5	70	5	15	16.5	Bad
18	a	15	70	5	1	12.32	Bad
19	b	5	88	5	4	15.72	Good
20	c	5	70	17	18	22.09	Bad
21	ab	15	88	5	6	21.81	Good
22	ac	15	70	17	10	22.12	Bad
23	bc	5	88	17	17	12.71	Bad
24	abc	15	88	17	5	22	Good

The quality of parts was determined by visual inspection. Figure 1 shows an example of "Good" and "Bad" parts produced in this experiment.

Fig. 1 Representative Parts Produced

Statistical analysis was performed using Analysis of Variance (ANOVA). The results are shown in Table 2. Analyzing the ANOVA table in Microsoft Excel, it can be observed that parameter A or cooling time is a significant parameter in this experiment. Using Minitab software, the same procedure was conducted and it had also revealed that cooling time was statistically significant to this experiment. The main effect plots and the interaction plots have shown in Figure 2 and 3 respectively. It can be seen that there could be an interaction between back pressure and plasticizing limit if more data was collected [1]. These two parameters did not have a statistical significant in decreasing the cycle time [2].

The graphs show that there could be an interaction between the plasticizing limit and the back pressure. The parameters did seem to interact with each other while running the experiment. A low back pressure and a high plasticizing limit or a high back pressure and a low plasticizing limit will give a good quality part. Running both of the parameters at a high and a low level gave a considerable amount of defects. The statistical evidence for getting a shorter cycle time shows that the only main effect was parameter A. This would recommend the only way to shorten the cycle time in this experiment for the best part produced.

Table 2 Statistical Analysis Results

Source	SS	df	MS	f-stat	p-value	f-critical
a	287.32	1	287.3184	76.524588	1.7073E-07	4.49399806
b	6.45	1	6.44806667	1.71738269	0.20853126	4.49399806
c	8.21	1	8.2134	2.18756283	0.15854728	4.49399806
ab	5.43	1	5.43401667	1.44729988	0.24646176	4.49399806
ac	2.90	1	2.89815	0.77189534	0.39263458	4.49399806
bc	4.70	1	4.69935	1.25162824	0.27975743	4.49399806
abc	5.88	1	5.8806	1.56624321	0.22874241	4.49399806
Error	60.07	16	3.75458931			
Total	320.891983	23				

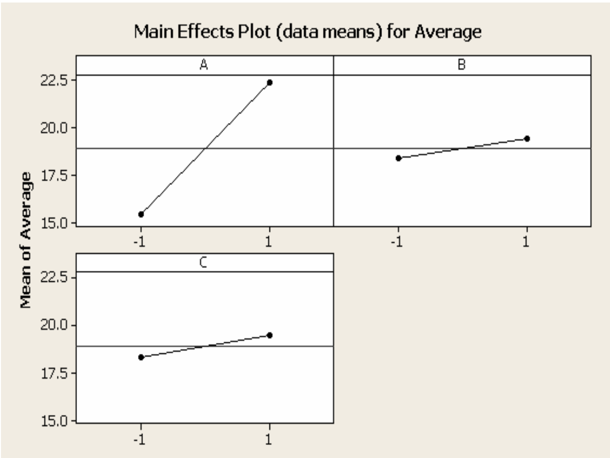

Fig. 2 Plot of Main Effects via Minitab

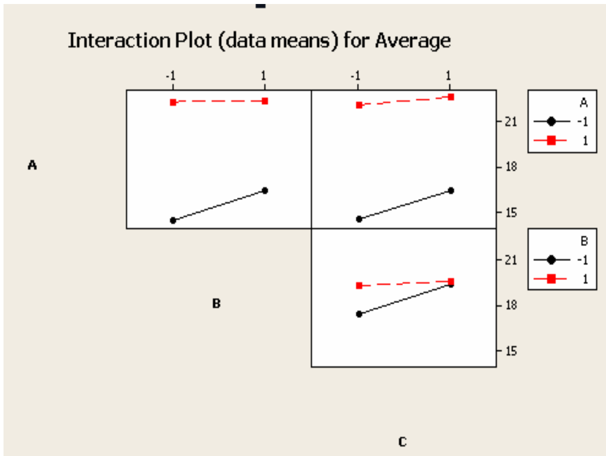

Fig. 3 Plot of Interaction via Minitab

Conclusions and Recommendations

Using a design of Experiments (DOE) has proven to be a major tool in discovering which parameters and interactions are significant to further improve an injection molding process. As proven here the only significant parameter was cooling time and it was the only parameter that had any major effect on the overall cycle time. By looking at the statistical data, this experiment proved that while assuming quality has been met, the process can be cut down by 6.92 seconds.

For further analysis, a further study would include more parameters, such as the temperature in the heating bands, for a more detailed experiment. Manipulating the four temperatures in the heating bands could decrease the cooling time which would decrease the overall cycle time.

Mini Tab and Excel would be a more effective way to do a statistical analysis on the injection molding machine when the designed experiment has increased the parameters and therefore increased the data involved in the analysis. Using these software packages could help engineers statistically analyze other manufacturing processes which may include high speed machining, pharmaceutical products, and electronic components to decrease cycle time or to even improve quality.

Bibliography

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Biography

JAMES P. HENDERSON received his bachelor's degree at Western Carolina University in Manufacturing Engineering Technology (2005). His area of interests includes quality assurance, lean manufacturing, and design.

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