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OPTIMISATION OF PROCESSING CONDITION USING TAGUCHI METHOD ON WARPAGE FOR HDPE- CLAY COMPOSITE

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Abstract. Injection molding is one of the most important processes in manufacturing nowadays. Thus, attention must be given towards the optimization of the product defects. Parameters have been chosen by screening tests to improve the process quality. The main purpose of this study is to optimize the processing condition using Taguchi Method on shrinkage for HDPE-Clay specimen. The experiment starts by preparing the mixture between HDPE and clay. Then, screening test is conducted to obtain the parameters. The parameters are melt temperature, injection speed, injection pressure and cooling time. By using the array orthogonal L_9 (3^4), signal to noise ratio and ANOVA were conducted. Based on the S / N ratio analysis, best combination can be produced for warpage (melt temperature: 190°C, injection speed: 40%, injection pressure: 30% and cooling time: 3 seconds). While for ANOVA, melt temperature is most significant with 60.28% for warpage.

Introduction

These days, injection moulding is gaining popularity due to the combination of near net shape processing of wide range of material[1]. It has been well established as it inherit many features compared to powder compaction such as low production cost at large quantity, good tolerance & mechanical properties, applicable to many materials and ability to sub-micrometer regime[2,3,4]. However there is some limitation in the process such as feedstock preparation, debinding and sintering[3,5]. For this project, High-density Polyethylene will be mixed with nano clay. Due to the problem of nano powders, optimisation technique has to be implemented in order to reduce defects and give higher shape retention[3]. Here, taguchi method will be implement to estimate the best parameter injection that suites warpage characteristics. Design of experiment(DOE) using taguchi method was used in this study to optimize the injection parameters and the experimental results are then transformed into a signal to noise ratio(SN Ratio)[6]. Analysis of variance(ANOVA) also been used to determine the contribution factors which influence the quality characteristics.

Experiment

This experiment consists of quality of part and the optimum parameter setting by determining their S/N ratio and their percentage of contribution. To find the percentage of contribution is by using ANOVA. The injection moulding machine used for this experiment is Nissei NP7-1F type as displayed in Figure 1.

Figure 1: Injection moulding machine Nissei NP7-1F type

Material Selection

The material used in this research was High Density Polyethylene (HDPE). The second material is clay. HDPE and Clay will be mix together. Table 1 shows the general properties of HDPE.

Table 1 : Properties of HDPE

Properties	
Hardness, Shore D	62
Tensile Strength, Ultimate Tensile	30 MPa
Strength, Yield	21.9 MPa
Elongation at Break	840
Melting Point	130°C
Vicat Softening Point	120°C
Brittleness Temperature	-86.2°C
Density	0.948 g/cc

Selection of Cavity Shape

The shape chosen for the mould cavity in this research was dumbbell shape. Figure 2 shows the dumbbell shape and its dimension based on International Organization for Standardization, ISO R527-2.

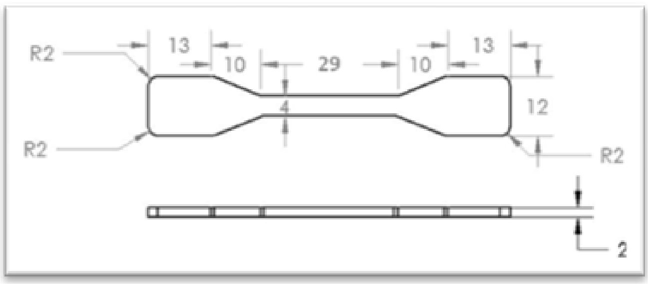

Figure 2: Cavity of dumbbell (dimension in mm)

Selection of Factors and Levels.

Based on the findings from ANOVA analysis, the factor selected and level values are illustrated in Table 2 while Table 3 show the values of orthogonal array selected ($L_9 3^4$).

Table 2 : Factor and level selection

Factors	Level 1	Level 2	Level 3
Melt Temperature (˚C)	135	163	190
Injection Speed (%)	20	40	60
Injection Pressure (%)	30	50	70
Cooling Time (s)	3	5	7

Table 3 : Values of Orthogonal Array

Factor / Experiment	Injection Moulding Parameter Level			
	A	B	C	D
	Melting Temperature, °C	Injection Speed, %	Injection Pressure, %	Cooling Time, s
1	135	20	30	3
2	135	40	50	5
3	135	60	70	7
4	163	20	50	7
5	163	40	70	3
6	163	60	30	5
7	190	20	70	5
8	190	40	30	7
9	190	60	50	3

MeasuringWarpage

The warpage of specimens was measured by using digital dial gauge. The procedure is needle need to touch the base and the specimen.

Result and Discussion

The result is focusing in the specimen warpage for each parameter and formulation. Using S/N ratio and ANOVA value, the quality of the specimen can be determined [1,2]. In this result also the correlation of the parameter and the S/N ratio value was plotted in a Figure 3. For the ANOVA analysis, the most contribution parameter can be determined [7]. The contribution of the parameter was base on the higher percentage of contribution. This percentage contribution was calculated for all formulation.

Analysis of Warpage

They have four combinations of matrix and clay which is 1% and 5%. Table 4 and 5 shows all combinations with their S/N ratio value and the example manual calculation of S/N ratio.

Table 4: Warpage Value and S/N Ratio for 1% Clay

No. Trial	Melt temperature (°C)	Injection speed (%)	Injection pressure (%)	Cooling time (s)	Hardness value	S/N Ratio (dB)
1	135	20	30	3	0.009	40.9151
2	135	40	50	5	0.014	37.0774
3	135	60	70	7	0.015	36.4781
4	165	20	50	7	0.017	35.3910
5	165	40	70	3	0.011	39.1721
6	165	60	30	5	0.02	33.9794
7	190	20	70	5	0.014	37.0774
8	190	40	30	7	0.015	36.4781
9	190	60	50	3	0.013	37.7211

Table 5: Warpage Value and S/N Ratio for 5% Clay

No.Trial	Melt temperature (°C)	Injection speed (%)	Injection pressure (%)	Cooling time (s)	Hardness value	S/N Ratio (dB)
1	135	20	30	3	0.013	37.7211
2	135	40	50	5	0.013	37.7211
3	135	60	70	7	0.019	34.4249
4	165	20	50	7	0.01	40.0000
5	165	40	70	3	0.008	41.9382
6	165	60	30	5	0.008	41.9382
7	190	20	70	5	0.006	44.4369
8	190	40	30	7	0.007	43.0980
9	190	60	50	3	0.006	44.4369

Based from Table 4 and 5, it shows that the range of S/N ratio are wider for 5% clay compare with 1% clay. It may happened because of the feedstock homogeneity and particle distribution during mixing where 5% clay provide better compact retention. The higher percentage of clay will give minimal amount of warpage as it contains bimodal powder packing. The difference between 1% clay and 5% clay was illustrated in a Figure 3 for average S/N ratio versus the level of parameter for four different parameters.

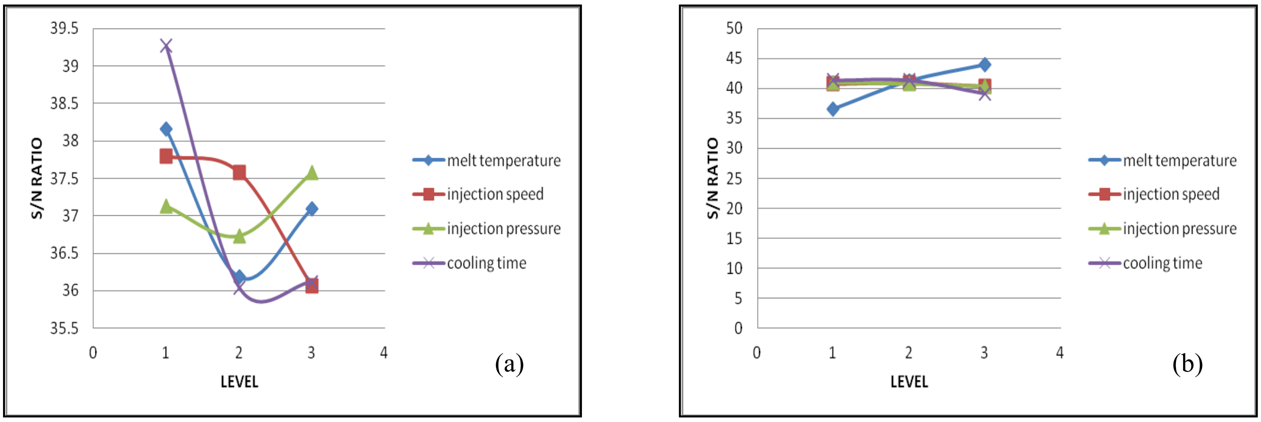

Figure 3: Graph Average S/N Ratio vs Parameter Level for Warpage for 1%(a) & 5%(b) of Clay

The S/N ratio of each interaction in Figure 3 is come from Table 4 and 5 where it clearly shows that $A_1B_1C_3D_1$ and A_3B_1 C_1D_1 were the highest mean S/N ratio. Hence, the optimum performance parameter can be achieved as it comes from the highest mean S/N ratio[8,9]. .From Figure 3, the optimum parameter for each formulation can be determined based from the highest mean S/N ratio. Table 6 shows the optimum parameter for warpage for each formulation.

Table 6 : Optimum Parameter for Warpage

Percentage,%	Optimum Parameter
1	A1 B1 C3 D1
5	A3 B1 C1 D1

Conclusion

Taguchi's orthogonal array is designed to improve the quality of products and processes where the performance depends on many factors. From screening experiment analysis, six parameters were tested. However injection time and cycle time parameter were eliminated since it is not significant to the analysis. As a results melt temperature, injection speed, injection pressure and cooling time were taken into considerations. In the injection molding, visible ejector marks will give significant effect to the experimental samples and warpage. Hence, it can be reduced by eject the sample in a cooling down temperature. Overall, optimum parameter for warpage has been achieved where the best combination is melt temperature 135^oC, injection speed 20%, injection pressure 70% and cooling time 3 second with 1% clay. For 5% clay, the best combination is melt temperature 190^oC, injection speed 20%, injection pressure 30% and cooling time 3 second.

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