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ANALYSIS OF SHRINKAGE AND WARPAGE ON FRONT PANEL HOUSING USING GENETIC ALGORITHM

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Abstract

This study focuses on the optimisation of the injection moulding parameters to minimise the shrinkage and warpage on moulded parts using Autodesk Moldflow Insight (AMI) 2012 software. The shrinkage and warpage of the parts were analysed in x and y axis. Mould temperature, melt temperature, packing pressure and packing time were selected as variable process parameters. Design Expert software was used as a means to analyse and optimise the selected parameter setting in order to reduce shrinkage and warpage on front panel housing. A polynomial model using Design of Experiment (DOE) was integrated with Response Surface Method (RSM) using Centre Composite Design (CCD) method and an anticipative RSM was interfaced with an effective Genetic Algorithm (GA) to find the optimum value of process parameters. The shrinkage and warpage of the moulded parts has been reduced down to 56 % and 68 % respectively after the optimisation.

Keywords: *Injection moulding, Response Surface Methodology, Genetic Algorithm, Design of Experiment.*

Introduction

Injection Moulding (IM) is classed as one of the most flexible and economical manufacturing processes with high volume of plastic moulded parts. The injection moulding process is a process is described as a process of when plastic material (a polymer that exhibits plasticising) is melted and then injected into a mould by pressure until the mould cavity was completely filled. After that, the part cools and solidifies into specific shape according to the shape of the mould cavity before being ejected [1].

Although the quality of the parts produced can be influenced by many factors, warpage and shrinkage are among the common factors that have effects on the quality of the part. Time consuming and high manufacturing cost causes conventional method using trial-and-error in a complex manufacturing process is no more suitable in determining the optimal process parameter in IM. Thus, the method used such as Taguchi, Genetic algorithm (GA), Artificial Neural Network (ANN) and many more was generated to find the best way to minimise the possibility of having defects on the part or model.

Several attempts have been made to optimise the parameters in reducing warpage and shrinkage of plastic parts. Amongst the optimisation works carried out in the pass was from Wu et al. [2] which reviewed the optimisation method on the injection moulding with line design

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constraint using Distributed Multi Population Genetic Algorithm (DMPGA) on digital photo frame. Polymethylmethacrylate (PMMA) was used as material to manufacture the digital photo frame with overall length was 218 mm × 150 mm × 4 mm. Moldflow Plastic Insight (MPI) software was used to analyse the filling pattern of the final optimal design by DMPGA. The authors asserted that the maximum part warpage which was 0.5599 mm before the optimisation, had reduced down to 0.1796 mm which is 67.92 % after optimisation.

From the research conducted by Zhao et al. [3], it shows that volumetric shrinkage had been reduced from 5.988 % to 4.782 % after optimisation. The authors investigated using the multi objective optimisation based on the improved efficient global optimisation algorithm (IEGO) and non-dominated sorting based genetic algorithm II (NSGA-II) on the Liquid Crystal Display (LCD). In this case, the Acrylonitrile Butadiene Styrene (ABS) AF 303 was used to manufacture the LCD front shell of 320 mm × 305 mm × 3.5mm.

Studer and Frank [4] suggested that the warpage can be possibly minimised further through an optimisation method. The authors investigated on an amount of material required to mould the gear box and casing cover. The Fibre Reinforced Polycarbonate was used to mould the gear box with the dimensions of 150 mm x 124 mm x 54 mm and the thickness of the initial design between 1.5 mm and 3.0 mm. Acrylonitrile Butadiene Styrene (ABS) Terluran GP- 22 was used as a plastic resin to mould the casing cover with the dimensions of 250 mm x 203 mm x 28 mm and the thickness of 2.5 mm as the initial design. As a result, the warpage on the casing cover reduced 49 % with the decrease of volume 12 %, while the warpage on the gearbox reduced 17 % with the decrease of the volume 30 % after optimisation using GA

Hakimian and Sulong [5] tried to minimise the warpage and shrinkage on the micro gears polymer composites (thickness less than 1 mm) produced by injection moulding process using Taguchi method. The amorphous Polycarbonate/Acrylonitrile Butadiene Styrene blend (PC/ABS), amorphous Polyphenylene Ether/Polystyrene (PPE/PS), and crystalline Polyoxymethylene (POM) was used to mould the micro gears. It was found that the value of shrinkage and warpage reduced 28.64 % and 14.02 % respectively.

Azaman et al. [6] also draws a conclusion that the volumetric shrinkage and warpage can be decreased by identifying the right parameters. The evaluation on the shrinkages and warpage on the wood filled polypropylene (PP) composite thin walled parts were formed by an injection moulding process. PP material was used to manufacture thin walled part with 55 mm x 50 mm and 0.7 mm thickness. Autodesk MoldFlow Insight was used to simulate and analyse the injection moulding process. The researchers asserted that the optimum parameters range is 40^{o}C - 45^{o}C for mould temperature, 20 s - 30 s for cooling time, 0.85 MPa for packing pressure and 15-20 s for packing time to achieve the best result of the shrinkage and warpage.

RSM method is amongst the widely tool used as a tool for model prediction and optimisation in various area [7-9]. It is an empirical model that can be used to define the relationship between various processing parameters and searches for the significance of these process parameters for the couple responses [10].

The developed GA selects chromosomes based on the objective value and the level of constraint violation. The fitness values of the chromosomes are biased towards the minimum objective value and the least infeasible set in crossover phase. Most of the GA in the literature converts the constrained optimisation problem into an unconstrained optimisation problem through penalty function before the solution. This brings the difficulty of an appropriate selection of the problem-dependent penalty coefficient that require user experience. In the program developed in this study, this difficulty is fully avoided since no problem dependent coefficient is needed [12].

Therefore, this study will examine the research on warpage and shrinkage using RSM interfaced with an effective GA. The model for this study was a front panel housing where moulded using ABS material.

For Genetic Algorithm (GA) solves an optimisation problem by simulating the biological evolution process, Darwin's theory of the fittest, as with other GA [11]. The solution starts with a set of potential solution referred as population or chromosomes in the literature. Chromosomes are in the form of bit strings and generated randomly. The chromosomes evolve during several generations, correspond to an optimisation iterations. A new generation was generated using the crossover and mutation technique. Crossover involves splitting a two chromosomes and then combining one-half of each chromosomes with the other pair, and mutation involves flipping a single bit of a chromosome. The chromosomes are then evaluated using a certain fitness criteria. The best one is kept while the others are discarded. This process repeats until one chromosome has the best fitness. The criteria of parameters in GA are the size of the population, mutation rate, number of generations, etc. [12].

Materials and Methods

Front panel housing was designed with straight cooling channels and sub-marine gate used in gating system. Figure 1 shows the detail of front panel housing with gating system. ABS Toyolac supplied by Toray Plastic was used as a plastic material. The properties of material is shown in Table 1. To ensure more accurate data of this study, machine specification as shown in Table 2 was settled in Autodesk Moldflow Insight (AMI) 2012 software during the simulation process.

Design of Experiment (DOE) was obtained using RSM to developed regression models for each response. These models were used in GA to optimise the selected parameters in order to reduce shrinkage and warpage of the moulded part. Mould temperature, melt temperature, packing pressure and packing time were selected as variable parameters of this study. The results after optimisation using GA will compared to the recommended result obtained in Fill, Fill + Pack and Cool (FEM) analysis.

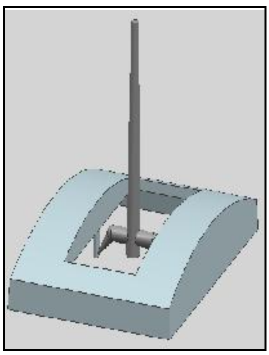

Fig. 1. Front panel housing with gating system

Table 1. Material properties of ABS resin.

Plastic Material	ABS
Grade	700-314
Mould shrinkage (ASTM D955) (%)	0.4 – 0.6
Minimum mould temperature (^oC)	40
Maximum mould temperature (^oC)	80
Minimum melt temperature (^oC)	220
Maximum melt temperature (^oC)	240
No flow melt temperature (^oC)	132

Table 2. Technical Specification for the Injection Moulding Machine, Nessei NEX1000

Injection Unit	Screw diameter, mm	28
	Injection capacity, cm^3	69
	Plasticising capacity, kg/hr	28
	Injection pressure, MPa	243
	Packing pressure, MPa	205
Clamping Unit	Clamping force, tf	80
	Clamping stroke, mm	300
	Mould thickness, mm	200 – 385
	Ejector force, tf	2
	Ejector stroke, mm	75

Simulation

AMI 2012 software was used as a medium for the simulation works. The analyses involve using AMI 2012 are Fill analysis, followed by Fill + Pack analysis and Cool (FEM) analysis to obtain the recommended processing parameters. Then, finally Cool (FEM) + Fill + Pack + Warp analysis to determine shrinkage and warpage results. 3D mesh is used for part and gating system consist of 179196 elements. Figure 2 shows the meshed model of front panel housing in AMI 2012 software.

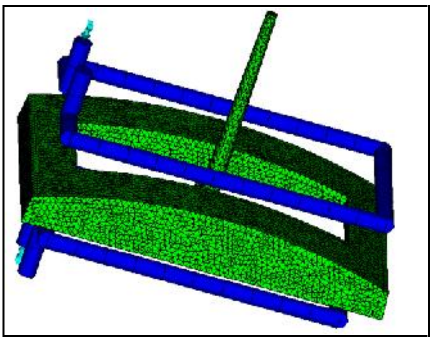

Fig. 2. Meshed model of front panel housing

Fill Analysis

The Fill analysis act to obtain the ram position by calculating the Shot Material (SM) in the reciprocating screw barrel. Referring to Equation 1, from the volume of front panel housing parts, the SM is equal to volume of part multiplying with an area of the barrel. About 15 % material was needed to add into SM that is forced into the mould recognised as a pressurisation phase. It is because plastic material can be compressed more into the mould and 25 % due to large volumetric change of plastic material. Therefore, starting ram position is shown in Equation 2 [13]. The fill analysis provides the result of fill time and shear rates with automatic setting in the filling control, automatic velocity/pressure switch over and default packing/holding control. The results of fill analysis are shown in Table 3.

$$SM = \frac{Volume\ of\ part}{\frac{\pi D^2}{4}} \qquad (1)$$

Starting Ram Position
= SM + 15 % (Material characteristic)
+ 25 % (Packing process) + 5 mm (Cushioning) (2)

Table 3. Result from Fill analysis

Fill analysis result	Value
Melt temperature (°C)	230
Mould temperature (°C)	60
Fill time (s)	2.8
Starting ram position (mm)	76
Shear rate (s^{-1})	58668

Fill + Pack Analysis

This analysis predicts the material flow into the mould cavities in filling and packing stage. From the Fill + Pack analysis, the packing time and packing pressure were obtained as shown in Table 4. In this analysis, the required injection pressure, velocity to pressure switch over point for the selected part were obtained. The velocity to pressure switch over was recommended by Autodesk Moldflow Insight (AMI) 2012 when the filling of the cavities reaches 99% [13].

Table 4. Result of Fill and Pack analysis

Fill + Pack analysis	Value
Fill + Pack time (s)	7
Packing pressure (MPa)	60
Velocity to pressure switch over (mm)	24

Cool (FEM) Analysis

Cool (FEM) analysis was used to determine the coolant inlet temperature and cooling time required for the front panel housing. This analysis was conducted to analyse the heat transferred from the molten plastic into the injection mould, coolant and environment until reached the ejection temperature based on the coolant temperature setting. From this analysis, the cooling time required was obtained to be 3.68 s.

Cool (FEM) + Fill + Pack + Warp Analysis

In this analysis, the Cool (FEM) + Fill + Pack + Warp was conducted to obtain the shrinkage and warpage (in x and y axis) on the front panel housing. The coordinates of the nodes on the moulded parts obtained from the AMI 2012 analysis are shown in Table 6, while Figures 3 and 4 show the measuring point (nodes position) of shrinkage which leads to the warpage defect on the front panel housing in x and y directions was determined. From the Fill + Pack + Cool (FEM) analysis results using AMI 2012, the distances between the nodes at positions A, B, C, D, E and F are shown in Figures 3, 4 and Table 5 were obtained. By inserting the nodes (615, 488, 603, 476, 726, 599, 1047, 1447, 867, 1267, 879 and 1279), the distances between the nodes at positions A, B, C, D, E and F appears as shown in Figure 5 which shows the distance between nodes N726 and N599 at position C (refer Table 5) before and after the deformation on the front panel housing.

Table 6. The coordinates of the nodes where the dimensions at positions A, B, C, D, E and F on the front panel housing were taken in AMI 2012 analysis.

Dimensions		**Measuring points**	
		From	**To**
Coordinate: x direction	**A**	Node 615 (-72.73, 115.65, -0.05)	Node 488 (47.87, 115.69, -0.05)
	B	Node 603 (-72.73, 77.81, -0.05)	Node 476 (47.87, 77.82, -0.05)
	C	Node 726 (-72.73, 38.65, -0.05)	Node 599 (47.87, 38.73, -0.05)
Coordinate: y direction	**D**	Node 1047 (-70.73, 117.57, -0.05)	Node 1447 (-70.73, 37.17, -0.05)
	E	Node 867 (-12.40, 117.57, -0.05)	Node 1267 (-12.42, 37.17, -0.05)
	F	Node 879 (45.98, 117.57, -0.05)	Node 1279 (45.98, 37.17, -0.05)

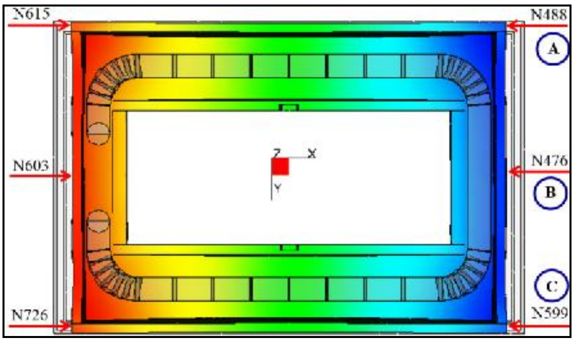

Fig. 3. Measuring point on front panel housing to measure the shrinkage which leads the warpage in x direction.

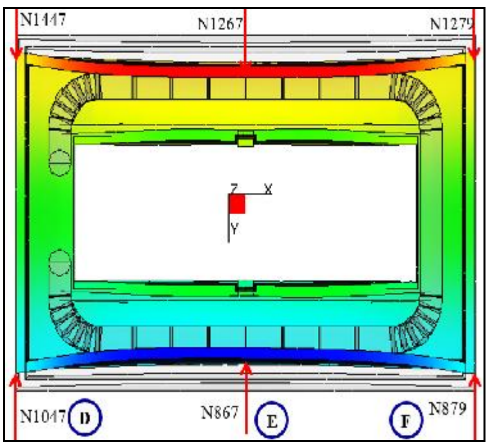

Fig. 4. Measuring point on front panel housing to measure the shrinkage which leads the warpage in y direction.

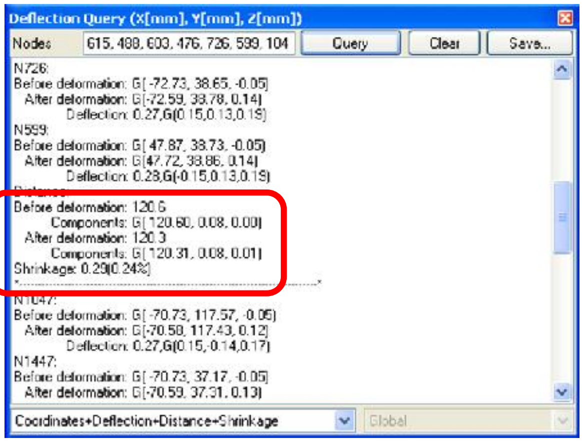

Fig. 5. Distance between nodes 726 (N726) and 599 (N599) at position C (Table 5) before and after deformation on front panel housing.

Design of Experiment

Two level full factorial design with four factors were selected as an experimental design to estimate the main effects of interactions for the shrinkage and warpage defects on the front panel housing using Design Expert 7.0 software. Mould temperature (^oC), melt temperature (^oC), packing pressure (MPa) and packing time (s) are four factors that used in this study. Levels for each factor are shown in Table 7.

Table 7. Factors and levels for DOE

Factors	Levels	
	Minimum	Maximum
Mould temperature, A (°C)	40	80
Melt temperature, B (°C)	220	240
Packing pressure, C (MPa)	30	70
Packing time, D (s)	3	10

Response Surface Methodology (RSM)

In this study, the curvature has been found as significant because the predicted value at the centre point is significantly different than the value that is obtained when actually running the centre point conditions. Thus the factorial design was augmented to Centred Composite Design (CCD) with alpha, α value is 0.05 to adequate the quadratic model of Response Surface Methodology (RSM). The empirical model in this study was obtained by using the quadratic model or also called second-order polynomial regression model. The necessary information to construct the response model are generally accumulated by the simulation work [14-15].

The factorial portion of CCD is a full factorial design with all combinations of the genes at two levels (high, +1 and lower, -1) and collected of the eight axial points and six central points (coded level 0) which is the midpoint between the high and low levels. The 30 run of experiments involved in this study was generated using the specified conditions, according to the rotatable CCD design in order to minimise shrinkage and warpage. In determining the shrinkage and warpage, the desired responses were seen as the smaller-the-better characteristic and influence each other relatively [15].

Results and Discussion

Analyses using Design Expert 7.0 indicated that packing pressure is the main factor that contributed to shrinkage and warpage defects, followed by mould temperature, melt temperature and packing time in both x and y directions. This is consistent with earlier findings by Hakiman and Sulong [6] and Wu et al. [2] who reported that the packing pressure is the most significant factor which reducing the shrinkage and warpage on the moulded parts. The shrinkage and warpage values in x and y directions obtained from simulation works for the combinations of processing parameters are summarised in Tables 9 and 10.

The equation was generated based on statistical analysis and results of shrinkage and warpage obtained from ANOVA. The equation is more significant if the value of R2 is closer to 1 and the value of adequate precision is more than 4. Referring to Table 8, the value of standard deviation indicates below 0.05 which is better in precision and reliability for the analysis [15]. Therefore, the equations 3, 4, 5 and 6 were obtained in RSM that can be used in the MATLAB programming software.

Table 8. Statistical analysis form ANOVA model for shrinkage and warpage on the front panel housing

	Shrinkage (%)		Warpage (%)	
	x	**y**	**x**	**y**
R-squared	0.9891	0.9848	0.8662	0.8954
Adjusted R-squared	0.9868	0.9823	0.8371	0.8356
Adequate precision	56.190	51.422	12.803	18.157
Standard Deviation	0.017	0.016	0.018	0.033

$$Shrinkage\ X = 0.44 - (1.29e^{-3})(A) - 0.019(B) - 0.19(C) - (1.296e^{-3})(D) - (8.750e^{-3})(AB) \quad (3)$$

$$Shrinkage\ Y = 0.85087 + (1.10103e^{-3})(A) - (7.63889e^{-3})(C) + (8.23413e^{-3})(D) - (1.63690e^{-4})(A \times D) \quad (4)$$

$$Warpage\ X = 50.25275 - (0.13117 \times A) - (0.010556 \times B) + (0.11620 \times C) + (9.34911e^{-4} \times A^2) - (8.69460e^{-3} \times C^2) \quad (5)$$

$$Warpage\ Y = -0.058241 - (8.05159e^{-3} \times A) + (9.51389e^{-4} \times D) + (4.0625e^{-5} \times A \times B) - (1.51786e^{-4} \times C^2) + (1.54812e^{-3} \times D^2) \quad (6)$$

Thus, these equations are needed to use in MATLAB for the next solution for shrinkage and warpage using Genetic Algorithm (GA) method.

Table 9. Results of Moldflow analysis for the warpage in x and y direction

RUN	A (°C)	B (°C)	C (MPa)	D (s)	Warpage (mm)	
					x	y
1	80	220	30	10.0	0.12	0.35 35
2	60	230	50	6.5	0.11	0.45
3	40	220	70	10.0	0.29	0.34
4	80	220	70	10.0	0.30	0.34
5	40	240	70	3.0	0.37	0.45
6	40	220	30	3.0	0.15	0.42
7	80	240	30	3.0	0.30	0.51
8	60	230	50	6.5	0.15	0.46
9	80	220	30	3.0	0.15	0.41
10	80	240	70	10.0	0.36	0.39
11	40	240	30	3.0	0.02	0.42

12	80	220	70	3.0	0.32	0.4
13	80	240	70	3.0	0.35	0.66
14	40	240	70	10.0	0.33	0.40
15	40	220	30	10.0	0.40	0.37
16	40	220	70	3.0	0.32	0.38
17	60	230	50	6.5	0.15	0.46
18	60	230	50	6.5	0.20	0.46
19	40	240	30	10	0.20	0.46
20	80	240	30	10	0.10	0.46
21	40	230	50	6.5	0.11	0.44
22	80	230	50	6.5	0.16	0.44
23	60	220	50	6.5	0.10	0.38
24	60	240	50	6.5	0.15	0.48
25	60	230	30	6.5	0.20	0.41
26	60	230	70	6.5	0.33	0.36
27	60	230	50	6.5	0.14	0.48
28	60	230	50	10.0	0.16	0.44
29	60	230	50	6.5	0.15	0.44
30	60	230	50	6.5	0.20	0.44

Table 10. Moldflow analysis result for shrinkage x and y direction

RUN	A (°C)	B (°C)	C (MPa)	D (s)	Shrinkage (mm)	
					x	y
1	80	220	30	10.0	0.63333	0.66000
2	60	230	50	6.5	0.47667	0.54666
3	40	220	70	10.0	0.27667	0.37000
4	80	220	70	10.0	0.27000	0.36000
5	40	240	70	3.0	0.20666	0.36666
6	40	220	30	3.0	0.64333	0.68666
7	80	240	30	3.0	0.62666	0.69666
8	60	230	50	6.5	0.43333	0.52000
9	80	220	30	3.0	0.64666	0.68333
10	80	240	70	10.0	0.21667	0.34000
11	40	240	30	3.0	0.61666	0.63000
12	80	220	70	3.0	0.30000	0.41000
13	80	240	70	3.0	0.22000	0.37000
14	40	240	70	10.0	0.24333	0.37666
15	40	220	30	10.0	0.64000	0.67666
16	40	220	70	3.0	0.24333	0.36333
17	60	230	50	6.5	0.43333	0.52000
18	60	230	50	6.5	0.43333	0.52000
19	40	240	30	10.0	0.62000	0.68666
20	80	240	30	10.0	0.61333	0.68000
21	40	230	50	6.5	0.47333	0.54333
22	80	230	50	6.5	0.42333	0.51333
23	60	220	50	6.5	0.49000	0.55333
24	60	240	50	6.5	0.43333	0.53000
25	60	230	30	6.5	0.62333	0.67333
26	60	230	70	6.5	0.34666	0.36666
27	60	230	50	6.5	0.44666	0.55666
28	60	230	50	10.0	0.42333	0.51333
29	60	230	50	6.5	0.42666	0.51333
30	60	230	50	6.5	0.42666	0.51333

Optimisation with Genetic Algorithm

In this section, minimum shrinkage and warpage within the range of the process parameter (this can be seen in Table 5) is by using the GA optimisation method. The shrinkage and warpage optimisation problem for the front panel housing with all input parameters (mould temperature (A), melt temperature (B), packing pressure (C), and packing time (D) can be defined in the standard

Optimisation with Genetic Algorithm

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Find: A, B, C, D

To minimise: Shrinkage (A, B, C, D)
Warpage (A, B, C, D)

Subjected to constraints:
Shrinkage and Warpage $\leq$ 1.5mm

Within parameter ranges:
$40°C < A < 80°C$
$220°C \leq B \leq 240\ °C$
$30\ MPa \leq C \leq 70\ MPa$
$3s \leq D \leq 10s$

Fig. 6. Standard mathematical format

To solve an optimisation problem in Equations 3, 4, 5 and 6 efficiently, a programming language was then written in the MATLAB software. The GA was developed and partnered with RSM and Finite Element Analysis (FEA) to optimise the shrinkage and warpage on the front panel housing as shown in Figure 7.

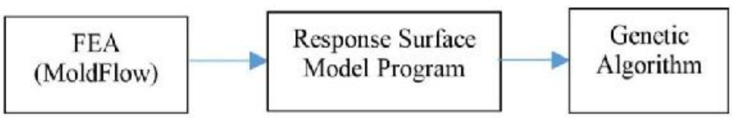

Fig. 7. Interaction of Finite Element software, RSM and GA during shrinkage.

For the shrinkage in x direction, the population size of 50 with a crossover rate of 1.0, the bit number for each variable are 19, 18, 19, 17 and the number of generations of 40 were employed. While, for the shrinkage in y direction, the population size of 50, crossover rate of 1.0, bit number for each variable are 19, 19, 17 and the number of generations of 40 are employed. On the other hand, for the warpage in x direction, the bit number for the variable are 19, 19, and 17. For warpage in y direction the bit number for the variable are 19,18,19,17, while the number of generations, population size and crossover rate for both directions are 40, 50 and 1.0.

The shrinkage in x direction on the front panel housing was reduced from 0.346 mm to 0.219 mm after optimisation using the GA method as shown in Table 11. Shrinkage distribution on the front panel housing based on the optimisation history in a generation was demonstrated in Figure 8.

Table 11. Injection moulding parameter before and after optimisation process for shrinkage in x direction.

	Injection moulding process parameter				Shrinkage, x direction (mm)
	Mould temp (°C)	Melt temp (°C)	Packing pressure (MPa)	Packing time (sec)	
Before optimisation	60	230	50	3.68	0.346
After optimisation	80	240	69	9	0.219

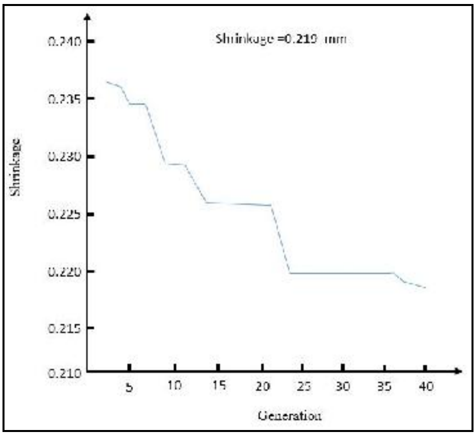

Fig. 8. Shrinkage optimisation using GA in x direction

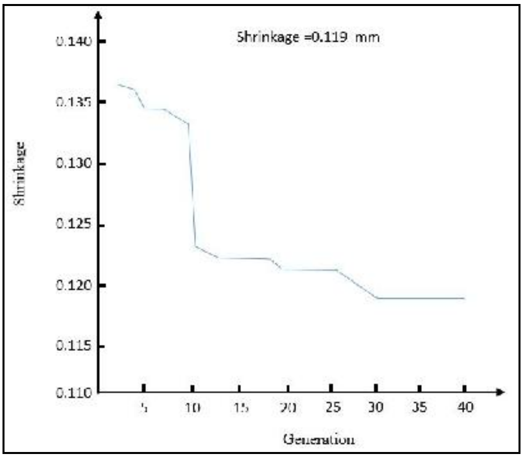

Fig. 9. Shrinkage optimisation using GA in y direction

On the other hand, the shrinkage in y direction on the front panel housing was reduced from 0.392 mm to 0.191 mm after optimisation using the GA method as shown in Table 12. Shrinkage distribution on the front panel housing based on the optimisation history in a generation was demonstrated in Figure 9.

Table 12. Injection moulding parameter before and after optimisation process for shrinkage in y direction

	Injection moulding process parameter			Shrinkage, y direction (mm)
	Mould temp (°C)	Packing pressure (MPa)	Packing time (sec)	
Before optimisation	60	60	3.92	0.392
After optimisation	80	69	9	0.191

The result of warpage on the front panel housing in x direction was reduced from 0.216 mm to 0.129 mm after optimisation as shown in Table 13 The graph in Figure 10 shows the warpage distribution versus the generation on front panel housing based on the value of generations set which is in this graph is for 0 to 40 generations.

Table 13. Injection moulding parameter before and after optimization process for warpage in x direction

	Injection moulding process parameter			Warpage, x direction (mm)
	Melt temp. (°C)	Packing pressure (MPa)	Packing time (sec)	
Before optimisation	230	50	3.68	0.216
After optimisation	230	70	10	0.129

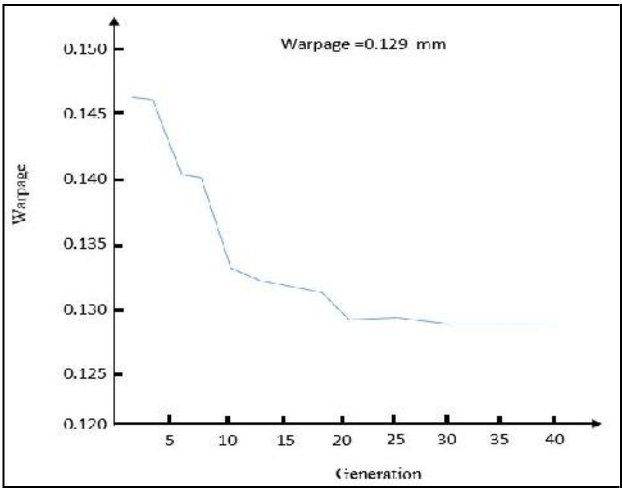

Fig. 10. Warpage optimisation using GA in x direction

On the other hand, the result of warpage on the front panel housing in y direction was reduced from 0.447 mm to 0.340 mm after optimisation as shown in Table 14. Figure 11 demonstrated the graph of warpage distribution versus generation on front panel housing based on the value of generation set, which for 0 to 40 generations.

Table 14. Injection moulding parameter before and after optimization process for warpage in y direction

	Injection moulding process parameter				Warpage, y direction (mm)
	Mould temp (°C)	**Melt temp (°C)**	**Packing pressure (MPa)**	**Packing time (sec)**	
Before optimisation	60	230	60	3.68	0.447
After optimisation	79	225	70	10	0.340

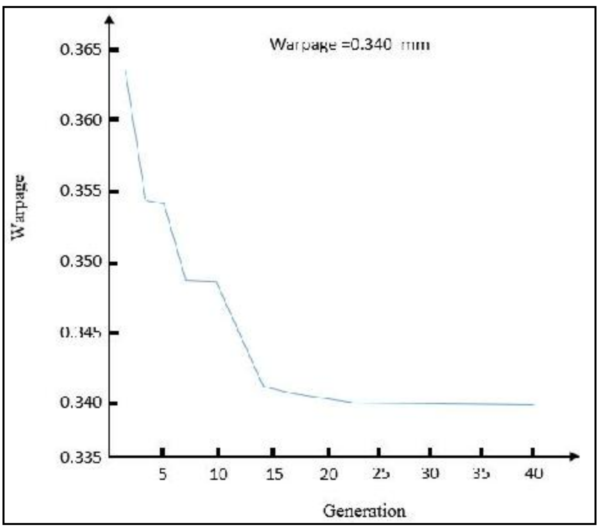

Fig. 11. Warpage optimisation using GA in y direction

Conclusion

In this study, an efficient optimisation methodology using Genetic Algorithm (GA) and Response surface methodology (RSM) has been introduced to estimate an optimal setting of processing parameters in an injection moulding process in order to minimise the shrinkage and warpage on a front panel housing. The mathematical model of the shrinkage has been carried out to find the correlational relationship between the dominant of the injection moulding parameters and mould front panel housing using ABS material. An optimal solution has been predicted based on a polynomial model created using Center Composite Design (CCD) in Response Surface Methodology (RSM). The analyses reported herein has proven that the shrinkage and warpage of the front panel housing can be reduced down to 56 % and 68 % respectively after optimisation. This indicates that, an optimisation methodology used in this study can also be employed to improve the similar plastic parts such as front panel housing in moulding industries.

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