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Analysis of Optimization Parameters for Plastic Injection Process Molding by Genetic Algorithm

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Abstract
Purpose: to analyze the optimum parameters in the injection molding of carbon fiber 66 (PA66) composite resin obtained from the injection molding process of the electrical connector assembly.
Design/methodology/approach: Experimental research will examine relevant parameters utilizing experimental design based on the Genetic Algorithm Method.
Findings The optimum parameters in the injection molding process are Injection Pressure at 110 MPa, Holding Pressure at 55 MPa, Holding Time at 1.0 sec, Injection Speed at 40 mm/s, Injection Stroke at value 15 mm, which will make the results of the injection workpiece produced from the injection machine be the length that is in the standard value.
Practical implications: The findings improved the molding problem: Short shot problem enhanced by 1.15%; Weld line problem improved by 0.38%; Silver mark problem enhanced by 0.11%.
Originality/value: Decrease the defect from a short shot problem in the injection molding process to save time and reduce production costs.

Keywords
Carbon fiber composite plastic 66; Connector assemblies; Short-shot; Genetic method.

Introduction

In the past few years, plastic injection molding technology has played an essential role in high-tech and traditional industries. The diversity and complexity of molded products, including the need for fast production and completion in a short period, are essential to the industry (Blanco et al., 2001; Chow et al., 2002). The plastic injection molding industry is highly competitive with market demand for good and cheap products. In recent years, plastics and polymers have rapidly developed to replace metals and alloys and other high-performance engineering applications, especially in the automotive industry, for both types of cars and motorcycles (Houck et al., 1995). The terminal block is an integral part of the signal connector and electrical circuit used in cars, motorcycles, and other equipment that needs to be connected for the signal.

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Polyamide 66 (PA66) was chosen due to its outstanding mechanical properties, which are lightweight and have good tensile strength (Cook et al., 2000). It is a plastic that is popular in general industrial applications. Plastic is a semi-crystalline polymer with high chemical resistance, good thermal and mechanical properties (Dilip et al., 2021; Du-Soon Choi et al., 1999), and excellent oil resistance. It is widely used in the aerospace, sporting goods, automotive, transportation, industrial, defense, and maritime industries (Zagar et al., 2020). It has specific properties suitable for producing assembly parts connectors due to its ability to reduce the rate of oxidation and thermal degradation when exposed to elevated temperatures for a long time. In addition, PA66 granules can maintain better physical properties in heat for a long time Goldberg, 2012; Herzog et al., 2013). Strength, durability, and high-temperature resistance, the impact is resistant even at low temperatures, easy to form, wear-resistant, and scratches well. It is an excellent electrical insulator, non-flammable, can be used in various applications, and can mix the color with plastic beads to get different colors of the workpiece as needed. This type of plastic resin can also add a mixture of hardness by adding or mixing carbon fiber according to the required hardness; in general, the ratio is 10–40%.

Literature review

In manufacturing, injection molding involves injecting molten polymer into a mold that cools the molten plastic and solidifies it into a plastic product. There are three processes: filling the plastic into the mold, plastic molding, and workpiece cooling process (Jiang et al., 2007). In the process of cooling, there are still residual stresses due to temperature changes and high pressure; the loosening of the polymer chain results in distortion of the part after ejection (Li et al., 2002), and other quality problems may occur. This shows that injection parameters are also essential factors for the quality of workpieces in determining the optimal parameters using a Genetic Algorithm (GA) for designing experiments to find optimum conditions with an Orthogonal Array to reduce time and waste of resources from many experiments. GA is a search algorithm designed to mimic the principles of biological evolution in natural genetic systems. The Genetic Algorithm, also known as the random sampling method, is used to solve difficult problems in the overall optimization of complex functions (Ghazali et al., 2010). In this situation, Computer-aided engineering (CAE) is a valuable tool for designing molds for plastic parts. Numerical simulation techniques and related CAE software such as Mold flow, Moldex, and Z-Mold have been developed, which can assist in mold structure design and selection of injection molding parameters (Naveen et al., 2021; Nuruzzaman et al., 2020).

Manufacturing processes, such as Injection Plastic Molding, are complex and difficult to optimize using conventional techniques. Evolutionary algorithms mimic living organisms in achieving optimal survival solutions and often outperform conventional optimization methods. Genetic Algorithms (GAs) have been widely applied to solve optimization problems in the past two decades. The first application of GA goes back to the 1960s, but only by the end of the 1980s, because of Goldberg's (Oktem et al., 2007) studies, did their application become prominent in the engineering community. Since then, GAs have become an optimization technique for solving complex manufacturing problems. Sadeghi (2000) also proposed a combined artificial neural network and GA method to optimize the injection molding process.

Sadeghi researched the article to determine the optimum parameters of the plastic injection molding process for the refrigerator top cover by a combination of Artificial Neural Network (ANN) and Genetic Algorithms (GA). The results showed that combining the two methods is an effective tool for optimizing the injection molding process. The ANN technique is an effective method for modeling complex relationships between conditions. The Genetic Algorithm is particularly suitable for finding a global optimization solution to a complex nonlinear problem. The proposed combination of ANN and GA methods is good for injection molding optimization. As a result, the quality of the workpiece with sink marks is significantly reduced.

Seow (1997) have compared warpage optimization in plastic injection mold using ANOVA, neural network model, and Genetic Algorithm (GA). An efficient optimization method using ANN and genetic algorithms has been introduced to reduce the warpage of thin-shell plastic parts produced by PC Button Base injection molding to achieve less distortion. The optimum process condition parameters, including mold temperature, melt temperature, packing pressure, packing time, gate runner, and cooling time, were the key elements used in the analysis using the statistical three-level factorial experimental design method. Finite Element Analysis by analysis of variance (ANOVA) found that the given parameters affected the distortion of the workpiece and used Artificial Neural Network (ANN) and Genetic Algorithm (GA) to find optimal parameters to optimize performance. The results of the research found that it can be improved at 51%

Somjate Patcharaphan (2019) studied the effect of injection parameters on the porosity of thin-walled aluminum die-cast parts, including Slow shot velocity, Fast shot set point, gate velocity, and Pressure rise time, which were analyzed using Multivariate linear regression (MVLR) and Genetic Algorithm (GA) analysis tools. The results showed that GA is an effective method for modeling the complex relationship between injection state and pore formation in casting aluminum parts. The paramotor value obtained from the simulation was used to experiment and measure the result. The optimum predicted porosity for casting is a minimum of 1.043%, but the actual yield is 1.076%, within the specified confidence range.

According to studies related to this case study, no research has yet conducted a parameter analysis to optimize the genetic injection molding of a motorcycle connector assembly with PA66 carbon fiber composite material to reduce short-shot problems. It is a crucial product where productions are made for domestic and export. The industry has a relatively high growth rate and production. If there is a large amount of waste in production, it will affect the factory in terms of quality, production costs, and delivery time.

Materials and methods

Research work piece

Terminal block-type products (Fig. 1 and Fig. 2) are parts used to assemble with other parts such as terminal workpieces, wires, and signal cables. The workpiece of the wire connector set is a part that connects the electrical circuit signal. The simulation model of Short Shot plastic part, with mesh geometry, shown in Fig. 1, was created. The geometry of this plastic part was discretized using Fusion mesh by MoldFlow, which is a commercial software based on a hybrid finite element/finite difference method for solving pressure, flow, and temperature fields. The part is made of PA66 (Polyacid 66) C9021 (Tsoukalas, 2009).

Fig. 1. Simulation 3D part

Fig. 2. Wire terminal block (connector)

Production quantity

From January to March 2023, the production data of the terminal block assembly was collected before the trial design of the case study factory (Table 1). It was found that the average production number was 51,937 pieces per month and there was an average defect problem of 1,416 pieces per month or 2.73% as shown in the bar graph of the data (Fig. 3 and Fig. 4).

Table 1
Production volume and the amount of production scrap in January to March 2023

Connector (Black)	Jan	Feb	Mar	Avg
Production (Pcs)	56,700	48,360	50,752	51,937
Defects (Pcs)	1,528	1,326	1,395	1,416
Defects (%)	2.69%	2.74%	2.75%	2.73%

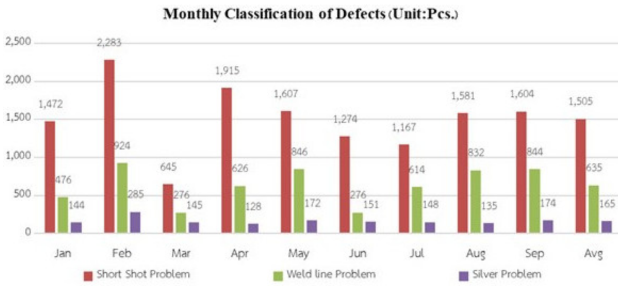

Fig. 3. Numbers of defects by problem from January to March 2023 (before improvement)

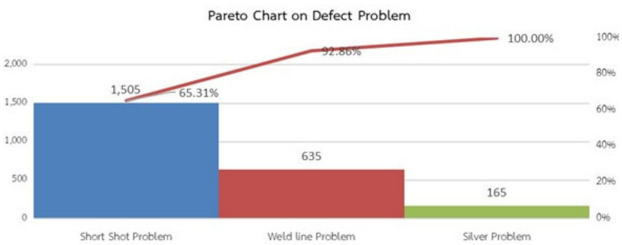

Fig. 4. Pareto chart on defect problem

Analysis data of defect amount before improvement

According to the amount of defects of the case study factory, there were 3 problems in the production process, namely Short shot problem, Weld line problem and Silver mark problem. The Short shot defect occurred the most with average of 980 pieces per month, followed by the Weld problem with average of 320 pieces per month and the Silver mark with average of 116 pieces per month, respectively, as shown in the data (Table 2), which is shown as a bar graph of the data (Fig. 5).

From all the defects problems that occur, the use of the Pareto chart helps in analyzing the root cause of the waste and fix that cause first because it will reduce the amount of waste as much as possible. It can be seen that the use of Pareto charts shows that the problem can be solved more directly (Yang & EI-Haik, 2009) by equation 1 and equation 2.

Table 2
Breakdown of wire terminal block defect types for the month of January to March 2023

Wire terminal block	Jan PCS	Feb PCS	Mar PCS	Avg PCS
Short shot	1,032	928	979	980
Weld line	389	274	298	320
Silver mark	107	124	118	116
Total	1,528	1,326	1,395	1,416
Short shot (%)	1.82%	1.92%	1.93%	1.89%
Weld line (%)	0.69%	0.57%	0.59%	0.61%
Silver mark(%)	0.19%	0.26%	0.23%	0.23%

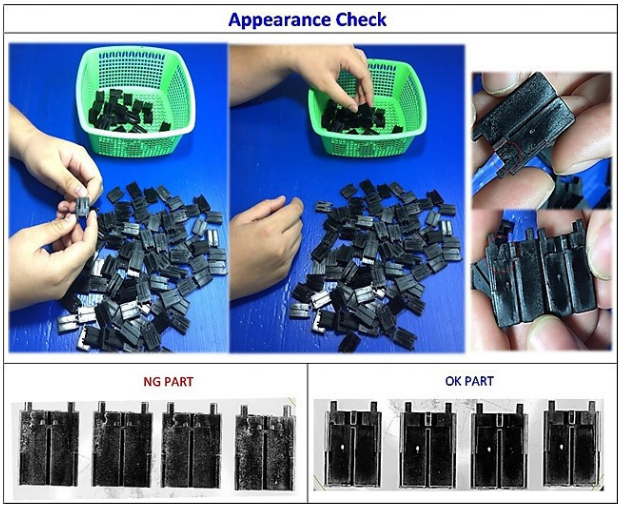

Fig. 5. Comparison between incomplete part (NG Part) and complete part (OK Part)

The cumulative distribution function takes a, b as parameters, $a > 0$, $b > 0$ and $x > b$

$$F(x) = 1 - \left(\frac{b}{x}\right)^a . \tag{1}$$

Probability function of the Pareto distribution

$$f(x) = \frac{ab^a}{x^{b+1}} . \tag{2}$$

It can be seen that the proportion of defects analyzed by Pareto graph (Fig. 6) from the shot short problem occurred the most, an average of 980 pieces per month, 69.17%, followed by the average number of weld line problems. per month, 320 pieces, 22.62% and the silver mark problem, the average monthly amount is 116 pieces, 8.21%, therefore the waste from the Short shot problem is taken to solve to improve and reduce waste in the production process that occurs.

Fig. 6. Smart scope camera measurement equipment

Images of defect pieces

Display images of parts that have Short shot problems in the production process compared to those that do not have quality problems. The way to detect quality problems is to measure the length of the lock jaw of the workpiece in all 4 cavities (Fig. 7).

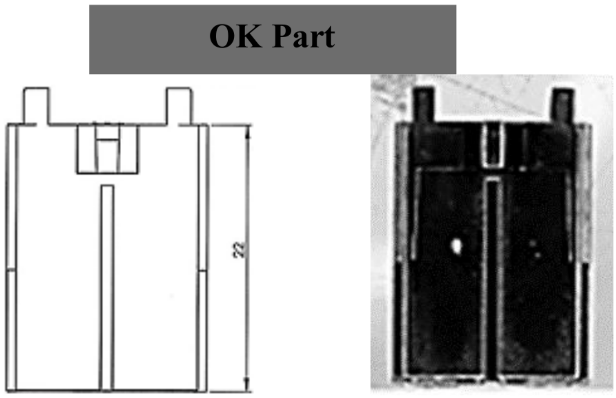

Fig. 7. The length of the lockjaw of the workpiece of the inspection point and the inspection image of the workpiece

Inspection process

Inspection of the workpiece quality (Fig. 8), use a tool called SSCM (Smart Scope Camera Measurement) to inspect the quality of the workpiece by measuring the length of the locking jaw of the workpiece, inspecting the workpiece must be full (Fig. 9) within the standard value according to the drawing (drawing). The size of the workpiece length is 22.00 + 0.30 mm. (length between 21.70–22.30 mm) piece. The number of work is 4 cavities per 1 shot production so that it can be realized that the workpiece will not have problems when it is used to assemble wires and connect the signal to equipment and the workpiece must not be deformed.

Fig. 8. Plastic Injection Machine – Toshiba Model EC50SXII

Fig. 9. Carbon fiber composite plastic resin (PA66) mixed with fiberglass at the level of 30 percent (Polyamide 66 + GF30%)

Injection process

Plastic Injection (Tsoukalas, 2009) is a process for forming plastic parts by relying on the injection molding machine (Fig. 10) that works in cycles. Initially, the plastic in powder or granule form is gradually fed into the injection screw assembly, melt in different temperature sections and injected into the mold by means of piston or screw compression. Liquid plastic water will flow into the mold until it is full and cool until the plastic hardens. Then, it is removed from the mold without deformation to get the plastic workpiece according to the design in that mold and continue the injection process again. In the research of the case study factory, a 50-ton Toshiba horizontal injection molding machine model EC50SXII was used.

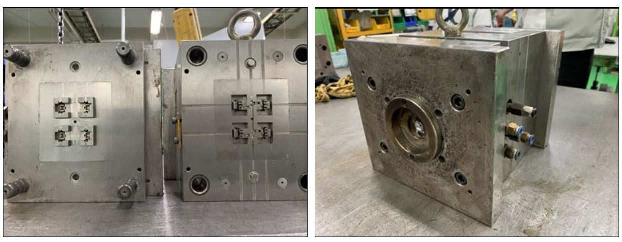

Fig. 10. Connector mold

Material

Carbon fiber composite plastic 66; Polyamide 66 (PA66 or Nylon66) (Houck et al., 1995) is often used in general industry due to its properties of durable plastic, easy to form and medium price. Properties of Carbon Fiber Composite Plastic 6 (PA6) and Carbon Fiber Composite Plastic 66 (PA66) are strong, durable and can withstand high temperatures, impact resistant even at low temperatures, easy to form, wear resistant and scratches well, excellent resistance to oil. It is a good electrical insulator and non-flammable. Carbon fiber composite plastic 66 (PA66) has a higher heat resistance than carbon fiber composite plastic 6 (PA6). Slightly, Carbon Fiber Composite Plastic 6 (PA6) has a nicer surface finish and easier to form than carbon fiber composite plastic 66 (PA66), carbon fiber composite plastic 6 (PA6) is more resistant to sunlight and UV radiation than carbon fiber composite plastic 66 (PA66). Carbon fiber composite plastic 6 (PA6) and carbon fiber composite plastic 66 (PA66) are plastics used in a variety of industries can be used to replace some parts made of metal due to its temperature resistance and chemical resistance. The raw materials used in this research (Fig. 11) are carbon fiber composite resins (PA66) mixed with fiberglass at the level of 30 percent (Polyamide 66+GF30%).

Production mold

Most characteristics of plastic injection molds consist of design of the mold in 2-plate or 3-plate type, depending on the nature of the workpiece. In the mold, there must be a cooling system within the mold, a release system and an ejector system, the size of the plastic water inlet (Runner gate) and a ventilation system used for production and research was a 3-plate mold with a site gate injection channel with 4 cavities and an ejector was used to eject the workpiece (Fig. 10).

Experimental process

Short shot problem analysis

According to related research, short-shot problems are the first defects found in the first step of the injection molding process, injection molding cavity is incomplete, especially at the end of the flow path or near points where the walls are thin. The problem was caused by:

1. Poor flow of plastic;
2. Insufficient injection temperature;
3. Insufficient injection pressure;
4. Insufficient injection speed;
5. Too low Plastic injection rate.

Therefore, based on the above information, each topic was used as a guideline for the study to determine the parameters of the factors affecting the defect for this research, consisting of

1. Plastic injection pressure parameters to control the problem factor in item 3, insufficient injection pressure.
2. Pressure in plastic injection molding to control the problem factor in item 3, insufficient injection pressure.
3. Pressure time in plastic injection molding To control the problem factors in item 3, insufficient injection pressure, and item 4, insufficient injection speed.
4. Plastic injection speed to control the problem factor in item 4, the insufficient injection speed.
5. Phase of plastic injection molding to control the problem factor in Section 5 is the plastic injection rate is too low.

As for the plastic parameter, the flow was not good enough because of the control of the melt temperature of the plastic in the injection machine, which was a factor in the study because the determination of the temperature of the plastic must use the melt temperature of each type, the type of material determines the value. The researcher must define a method to control the parameters in order to minimize the variance caused by external factors and in defect reduction (Yang & El-Haik, 2009) to eliminatewaste found in production.

Results

Determination of factor parameters and factor levels used in the experimental design

From the information of the Short shot problem and from the information of the parameters currently used in plastic injection molding. To study the factors that affect the problem, it is necessary to limit the factors affecting the partial injection problem and use the experimental design method in order to find the parameters and optimum conditions for plastic injection, to calculate the factors that cause the problem of injecting parts that are not full to occur the least. In this research study, the parameters from the current usage will be combined with the study of the research related to the parameters that affect the problem of insufficient injection (The study of short-shot water) – assisted injection molding of short glass fiber reinforced polypropylene.

Parameters used for that research, the researcher has chosen to use the current parameters of the case study factory to analyze and solve the problem together with the study. from short-shot water-assisted injection molding of short glass fiber-reinforced polypropylene) in conjunction with the simulation of plastic parts to validate the model using Mold Flow analysis Operating System: Windows 7 Service Pack 1, Processor type: Genuine Intel Intel64 Family 6 Model 94 Stepping 3 ∼ 3408 MHz, Number of Processors: 8, Total Physical Memory: 16304 Mbytes, Mesh Type = 3D Tetrahedra, Number of nodes = 121056, Number of beam elements = 70, Number of triangular elements = 418, Number of tetrahedral elements = 675368 for which the parameter values shown in Table 3 will be used in this study and control other related factors to cause minimal disturbance to the main control parameters and to avoid problems by controlling the coolant at 80°C at Core and Cavity sides to avoid heat loss. The melting temperature is between 285 to 295°C. This makes it possible to determine the factors of important parameters that affect quality in the production process that cause Short shot problems to be used in setting parameters for 5 parameters, consisting of Injection Pressure, Holding Pressure, Holding Time, Injection speed and Injection stroke.

Table 3
Parameters and parameter levels in experimental design

Parameters	Parameter levels			Unit
	1	2	3	
Injection Pressure (PI)	105	110	115	MPa
Holding Pressure (PS)	45	50	55	MPa
Holding Time (TRH)	0.5	1.0	1.5	sec
Injection speed (VI)	40	45	50	mm/s
Injection stroke (LS)	10	15	20	mm

The main objective of this research was to analyze the optimum parameters for the injection molding process to improve part quality using GA. Design and Analysis of Experiment: DOE (Zhong et al., 2020) method was used to reduce the time and resource waste from a large number of experiments, for which DOE is a quality tool to conduct experiments according to the model for which they were designed to find the relationship of various variables then create a static equation. Genetic Algorithm (GA) method has been used over the years to improve products and manufacturing processes. It is an efficient and effective way to solve the problem of product quality (Blanco et al., 2001), which is an estimated relationship between independent variable terms, often Quality Characteristics with dependent variables, Process/Product Variables, which will help to adjust the process to produce the results we want. In this research, an experiment was designed to study optimal parameters by using an experimental design to collect data using a matrix experiment design. The experimental plan was carried out according to the orthogonal array L27, which was used for designing the experimental study of process factors with 5 factors, each factor having 3 levels, as shown in Table 4. The data analysis was conducted by Minitab 19 Statistic software to calculate the correct and appropriate factors used in the experiment.

Table 4
Genetic Algorithm (GA) technique experimental design and experimental results

PI	PH	TRH	VI	LS	N	Length (mm)	S/N Ratio
105	45	0.5	40	10	N1	21.9949	46.6219
105	45	0.5	40	15	N2	22.0256	46.2986
105	45	0.5	40	20	N3	22.0209	45.4015
105	50	1	45	10	N4	22.0015	47.5063
105	50	1	45	15	N5	22.024	48.1386
105	50	1	45	20	N6	21.986	45.6979
105	55	1.5	50	10	N7	21.9851	47.6322
105	55	1.5	50	15	N8	21.9895	47.9146
105	55	1.5	50	20	N9	21.9932	46.2538
110	45	1	50	10	N10	22.0034	46.402
110	45	1	50	15	N11	22.0131	46.5139
110	45	1	50	20	N12	22.0169	48.3289
110	50	1.5	40	10	N13	22.0057	46.3728
110	50	1.5	40	15	N14	22.0032	48.2627
110	50	1.5	40	20	N15	22.0051	45.8021
110	55	0.5	45	10	N16	21.9823	46.4859
110	55	0.5	45	15	N17	21.9913	47.4977
110	55	0.5	45	20	N18	21.9946	48.3571
115	45	1.5	45	10	N19	22.0123	48.8133
115	45	1.5	45	15	N20	22.0379	48.4222
115	45	1.5	45	20	N21	21.9954	47.1965
115	50	0.5	50	10	N22	21.994	46.0161
115	50	0.5	50	15	N23	21.9959	48.9763
115	50	0.5	50	20	N24	22.0265	46.8025
115	55	1	40	10	N25	22.0099	47.0731
115	55	1	40	15	N26	21.9752	47.4081
115	55	1	40	20	N27	22.0024	46.9087

Then collect the data according to the designed experiment and calculate the Signal to-noise ratio by measuring the process response which was the percentage of shrinkage of the workpiece and calculating the S/N ratio. In this research, the quality system is Target – the better as it requires values that are within or very close to the control size based on the analysis results of Genetic Algorithm (GA) experimental design and processing with Minitab 19, the analytical results are shown in Fig. 11.

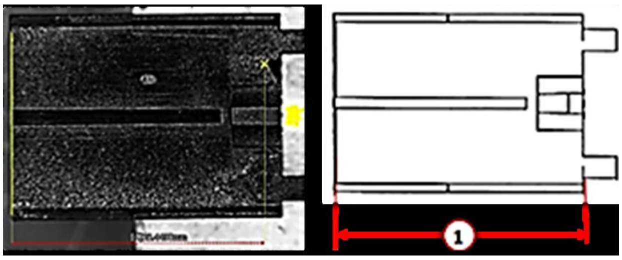

Fig. 11. Measuring point of controlled workpiece

Genetic Algorithms (GA)

Genetic methods are search algorithms that mimic the principles of biological evolution based on natural genetic systems. Based on the Stochastic global model, the design parameters were optimized using genetic methods. which genetic method to better find that answer, the "survival of the fittest" strategy begins with the definition of Fitness Function: Selection, Crossover, and Mutation; Chromosome representation, genetic operator selection function constituting a reproductive function, Initial population generation, Termination criteria, and Evaluation function.

Fitness Function

Genetic methods find the best solution based on the Fitness Function of each population. Fitness Function should reflect the performance of each population. In the current problem, Fitness Function defines it as: The best person in a population is the person with the best objective value.

$$\begin{aligned}\text{Fit } f(x) &= f(x), \text{ if the objective function } f(x)\\ &\qquad\qquad \text{is the maximum problem;}\\ \text{Fit } f(x) &= \frac{1}{f(x)}, \text{ if the objective function } f(x)\\ &\qquad\qquad \text{is the minimum problem.}\end{aligned} \tag{3}$$

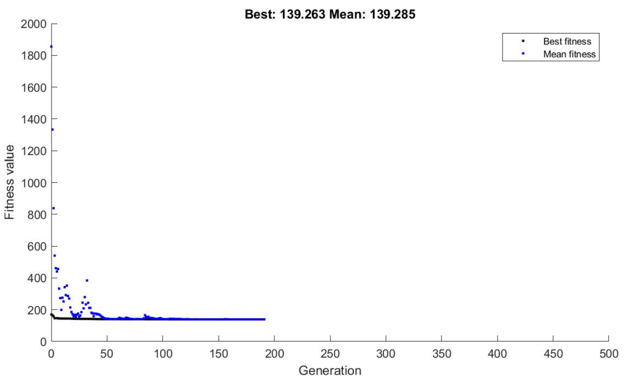

Fig. 12. Repeated Fitness Value

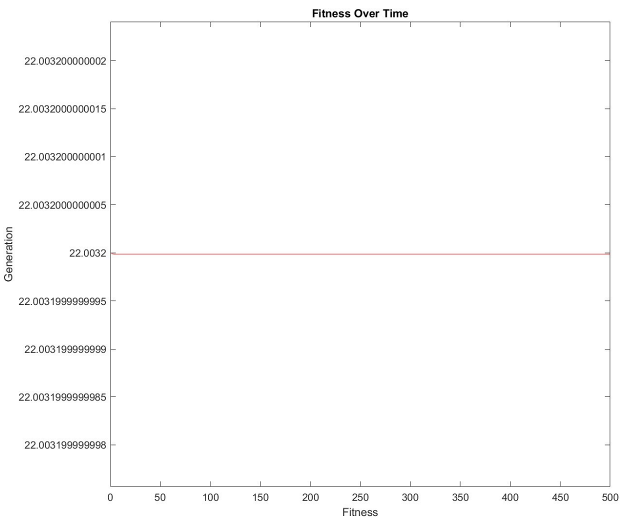

Fig. 13. Fitness Generation Value of work piece distance

Selection operation

There are several GA selection operations such as Roulette method and Tournament method. In this study, Roulette method was chosen. Namely, the optimum ratio strategy. The selection probability of each individual i is shown as follows.

$$
\begin{aligned}
f_i &= k/M_i\,,\\
P_i &= \frac{F_i t(fi)}{\sum\limits_{i=1}^{N\rho_0\rho} F_i t(f)_i}\,,
\end{aligned}
\tag{4}
$$

where M_i is the individual fitness, i in this study. The fitness value should be as small as possible, so the inverse is performed for each pre-selection fitness value. k is the coefficient, while N is the number of individual organisms.

Genetic operators

The genetic method consists of two main operators.

Crossover

Crossover combines information from a good solution “Parents” from both parents to crossover to create a new better solution with formulated equations of genetic methods; GA(31) for use in optimizing injection molding processing parameters.

$$
\begin{aligned}
y_i^1 &= r x_i^1 + (1-r)x_i^2\,,\\
y_i^2 &= r x_i^2 + (1-r)x_i^1\,.
\end{aligned}
\tag{5}
$$

Mutation

Mutation operations consisted of randomly changing the values of individual chromosome elements according to their probability of mutation, Nonuniform mutation [32, 33] for the real coded GA as formulation [34] is used.

$$
x_i^x = \begin{cases} x_i + (b_i - x_i) f_{(G),i} f_{r_1} < 0.5,\\ x_i - (x_i - a_i) f_{(G),i} f_{r_1} > 0.5, \end{cases}
\tag{6}
$$

where

$$
f(G) = \left(r_2\left(1 - \frac{G}{G_{\max}}\right)\right)^b.
\tag{7}
$$

Here, a_i, b_i are the lower and upper bounder of each variable i; G, $G_{\max}$ are current generation and maximum number of generations. r_1, r_2 are random numbers between (0, 1). b is a parameter, chosen by the user, that determines the degree of dependency on the number of iterations (Seow, 1997).

Therefore, the distance magnitude of length is chosen as the objective function. There are many factors and levels of parameters that influence the problem. The most influential variables selected by Genetic Algorithm (GA) DOE include:

PI is Injection Pressure.
PS is Holding Pressure
TRH stands for Holding Time.
VI is Injection Speed
LS stands for Injection Stroke.

so

Find: PI, PS, TRH, VI, LS
Minimize: Workpiece length
Subjected to constrain: Length of 21.70–22.30 mm.
Within ranges:
105 MPa < Injection Pressure (PI) < 115 MPa
45 MPa < Holding Pressure (PS) < 55 MPa
0.5 sec < Holding Time (TRH) < 1.5 sec
40 mm/s < Injection Speed (VI) < 50 mm/s
10 mm < Injection Stroke (LS) < 20 mm

The important parameters of a genetic algorithm to solve an efficient optimization problem are population size, mutation rate, and number of repetitions. In this research, Population size was set at 50, Crossover probability at 0.9, Mutation probability at 0.1, and Maximum of generations at 500 were set and optimization with iteration was performed for the Short-shot problem. The figure shows that after 139.263 iterations as in Fig. 14, with the parameter that minimizes the length of the short shot problem of the injection molding process.

Fig. 14. Input parameters obtained from the analysis for the trial production

Experimental analysis

From Fig. 15 and Table 5, the parameters that cause the length of the short shot problem of the injection molding process to be the least, and from Table 6 shows the results of the analysis of the workpiece length obtained from the parameters. The analysis results show that Injection Pressure at 110 MPa, Holding Pressure at 54 MPa, Holding Time at 0.6234 sec, Injection Speed at 42 mm/s, Injection Stroke at a value of 15 mm can inject the workpiece close to the specified standard size, which is $22 + 0.30$ or between the values of 21.70 to 22.30 mm. It was found that the Lower value from the analysis will inject the workpiece at the distance value of 21.9998 mm, the target value from the analysis will inject the workpiece at the distance of 22.0012 mm and the upper value from the analysis will inject the workpiece at the distance of 22.0025 mm.

Fig. 15. Injection molding process in production

Table 5
Parameters from GA analysis

Parameter	PI	PH	TRH	VI	LS	Size (mm)
GA Algorithm Optimization	110	54	0.6234	42	15	22.0000

Table 6
Length of work piece from GA analysis

Response	Goal	Lower	Target	Upper
Size (mm)	Target	21.9998	22.0012	22.0025

Trial production

The researcher used the parameters obtained from genetic analysis (GA) and adjusted them to integers to be used to input the parameters into the injection molding machine (Table 7).

Table 7
Parameter that adjust into round number

Parameter	PI	PH	TRH	VI	LS
Adjust GA Algorithm Optimization	110	55	1	40	15

In the trial production, the parameters consist of Injection Pressure at 110 MPa, Holding Pressure at 55 MPa, Holding Time at 1.0 sec, Injection Speed at 40 mm/s, Injection Stroke at 15 mm (Fig. 14, Fig. 15) to collect the results to compare the results before and after.

Discussion

Defects amount after improvement

From the experimental results that the parameters have been used in the actual production from April to June 2023, it was found that the waste problem caused by the quality of the parts of the terminal block has decreased. The data are shown in Table 8.

The main problem that needs to be improved is the Short shot problem that has decreased in number.

Table 8
Production volume after improvement

Wire terminal block connector	2023			Avg
	April	May	June	
Numbers of production	31,600	51,106	58,762	47,156
Numbers of defects	502	449	467	473
Defect %	1.59%	0.88%	0.79%	1.00%

With an average of 321 pieces per month, and in this improvement, this also affects the 2nd problem and the 3rd problem that occurs to decrease accordingly. These include the Weld problem with an average of 103 pieces per month and the silver mark problem with an average of 49 pieces per month, as shown in Table 9.

Table 9
Production and defects volume from April to June 2023

Wire terminal block connector	2022			Avg
	Oct	Nov	Dec	
Short shot problem	342	305	317	321
Weld line problem	108	98	102	103
Silver mark problem	52	46	48	49
Total	502	449	467	473
Short shot problem (%)	1.08%	0.60%	0.54%	0.74%
Weld Line problem (%)	0.34%	0.19%	0.17%	0.24%
Silver mark problem (%)	0.16%	0.09%	0.08%	0.11%

Conclusions

Parameters in plastic injection

It was found that the factor that affected the length of the injection molding process was not full. The parameters of the Holding Pressure and the most suitable parameters in the injection molding process of PA66 raw materials are Injection Pressure at 110 MPa, Holding Pressure at 55 MPa, Holding Time at 1.0 sec, Injection Speed at 40 mm/s, Injection Stroke at value 15 mm, which is in the standard value and close to the central control value the most and has the least effect on short-shot problems

The workpiece obtained from the parameters before and after the improvement by the SSCM (Smart Scope Camera Measurement) tool, it was found that before the improvement there was an average number of defects that occurred at 1,416. pieces per month or 2.73%, divided into short shot problems, an average of 980 pieces per month or 1.89%, an average weld line problem of 320 pieces per month or 0.61% and an average silver mark problem of 116 pieces per month or 0.23% which after improvement found that the average number of defects occurred was 473 pieces per month or 1.0% divided into Short-shot problems averaged 321 pieces per month or 0.74%, weld line problems averaged 103 pieces per month or 0.24% and the average silver mark problem is 49 pieces per month or 0.11%

This finding minimizes the problem of Not OK pieces of Short shot problems, weld line problems and silver mark problem; therefore, the production can be done faster and save the cost of production. The defect decreased by 173% or 1.73 times after using GA to improve the production (Before = 2.73%, After = 1.0%). This finding helps the factory to set up appropriate production parameters to mitigate the injection mold problems.

The experiment is limited because it was done only at one factory with a specific mold pattern.

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