Original Research

Applying Taguchi Method to Optimize Parameter of Injection Molding Process

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Abstract
Direct Memory Access (DMA) is a device that performs the function of transferring data between memory and peripheral devices without the intervention of the main processor device (CPU). However, DMA's manufacturing environment is based on trial-and-error testing, and DMA equipment manufacturing conditions depend on craftsmanship and experience, which does not guarantee product quality, leading to up to 99% defective products, increasing production costs and reducing customer satisfaction. This study proposes the Taguchi method to optimize the Mold process to minimize the number of experiments according to the orthogonal grid L18 with factors including nozzle size (mm), Mold temperature (℃), Mold plastic pushing pressure (Mpa), Binder chemical concentration (%), Mold material weight (g), and Molding time (min) are selected to perform cause-and-effect analysis. Results from the experimental analysis of process evaluation, in addition to meeting the target values of mold temperature, mold pressure, and mold material weight at the mold process, also need to improve the quality of surface cleanliness of the DMA plate at the plasma process, demagnetization on the DMA plate below 2 Gause helps improve the accuracy of the Mold process.

Keywords - Direct Memory Access (DMA), Orthogonal array (OA), Taguchi method, Mold plastic.

INTRODUCTION

The manufacture, research, and development of semiconductor devices, including integrated circuits, transistors, diodes, sensors, and many other electronic components, are primarily carried out by the semiconductor industry, which is a significant sector of the economy. Power semiconductors are the fundamental building blocks of integrated circuits (ICs), which are used in computers, mobile phones, tablets, networking equipment, smartphones, and other telecommunications devices [1-2]. Products from the power semiconductor industry are widely used in technology fields, including Information technology and telecommunications. Microprocessors, memory, and other semiconductor electrical components used in consumer goods including TVs, cameras, smart home appliances, LED lights, and more are referred to as consumer electronics technology additional electrical gadgets [3]. Modern automobiles rely heavily on semiconductors for everything from the engine and control systems to the safety features, entertainment systems, and sensors [4]. The development and manufacturing of electronic devices including solar cells, lithium-ion batteries, and control electronic systems in projects are aided by the power semiconductor industry of renewable energy, repurposed power, healthcare as Medical sensors, radiation machines, diagnostic imaging machines, and health monitoring devices all use semiconductors [5]. Power semiconductors are a measuring and control technology used in automatic measurement and control equipment in scientific measurement equipment, precision electronics, and industrial automation [6]. With technological advancements and increases in semiconductor device power and transparency, the power semiconductor market is changing quickly. Prominent firms in the sector encompass Intel, Samsung Electronics, TSMC, Qualcomm, Nvidia, and an extensive array of other multinational corporations [7-8].

Semiconductor devices require DMA (Direct Memory Access) in a wide range of applications. Data is frequently sent directly between memory and semiconductor devices, including network cards, graphics cards, hard drives, and RAID controllers, via DMA [9]. Semiconductor devices can transmit data directly between memory and themselves without the need for a CPU by using DMA. Data transfer speed is accelerated and the CPU's workload is decreased as a result [10]. Through DMA, semiconductor devices may transfer huge blocks of data fast and efficiently, eliminating the need for the CPU to process each individual byte of data. DMA enables the drive to send data straight to memory, bypassing the CPU, when you copy a file from a hard drive to memory [11]. The CPU only needs to establish and set up the DMA records; after that, it can carry out other duties while the data is sent automatically. Due to its ability to boost data transmission speeds and enhance performance, DMA is essential for semiconductor devices. It lessens the workload on the CPU and enables effective data transfer from semiconductor devices without causing the system to lag [12].

Inadequate DMA quality could have an impact on semiconductor device performance and functionality. Here are a few possible outcomes, including decreased performance as a result of DMA of low quality, which can cause data transmission to work less well. Data transmission may become sluggish or result in mistakes if DMA crashes or malfunctions [13]. Device reaction times may rise and data transmission speeds may decrease as a result. Data inaccuracies data transfer issues may arise when the DMA is malfunctioning. When data moves between memory and a device, it could be lost or distorted. Serious issues including system faults, the loss of crucial data, or unstable device performance may result from this [14]. System crashes might occur as a result of improperly deployed or configured DMA. System crashes, unintentional reboots and other problems with system dependability and stability could result from this. Inefficient DMA execution raises power consumption, which can raise power consumption in devices. Inadequate DMA operations or inefficient data transfers can shorten battery life or system power, waste energy, and raise power consumption. It is crucial to properly design, implement, and configure DMA and to make sure it complies with quality standards and requirements in order to prevent these issues [15]. For semiconductor devices to operate reliably throughout research and manufacturing, inspection, testing, and performance assurance are crucial.

Improving quality and reducing quality costs in production is accomplished by integrating Taguchi optimization techniques and statistical methods with the use of orthogonal arrays (OA) along with analysis tables using analytical methods variance (ANOVA) using samples tested in a real production environment in the manufacturing process [16]. The Taguchi empirical optimization method is highly appreciated in real production processes at manufacturing companies [17]. The objective of this research is to apply the Taguchi method to find optimal machining conditions in the Mold process of the DMA product line as an object for practical research. Perform parameter analysis of Injection Mold conditions at the DMA mold process with the least number of experimental studies without the need for additional equipment or supporting processes.

This research paper is structured as follows: Section I provides an introduction. Section II presents content related to the DMA equipment manufacturing process. Section III presents the cause-and-effect analysis of the subject the research is similar to DMA injection mold. Section IV optimizes the parameters of the DMA injection mold process using the Taguchi method. Section V presents the conclusions of the study.

RELEVANT BACKGROUND

I. Direct Memory Access (DMA) Manufacturing Process

The production process of DMA (Direct Memory Access) components is carried out through 3 main processes: Process 1 (Plasma cleaning process), process 2 (Injection Mold process), and Process 3 (Final Inspection).

Process 1 (Plasma cleaning): The process of cleaning surfaces with an affected plasma or dielectric barrier discharge (DBD) plasma produced from gaseous species is known as plasma cleaning. It uses mixtures like air and hydrogen/nitrogen as well as gases like oxygen and argon (Figure 1). The process of cleaning and sanitizing the surfaces of different materials using plasma, a state of matter in which atoms and molecules are separated and ionized, is known as plasma cleaning. It is frequently used in the industrial setting to clean materials' surfaces of contaminants, oil, grime, and other residues before conducting further procedures like electroplating, film coating, or bonding. An equipment known as a plasma cleaner or plasma etcher is frequently used to carry out the plasma cleaning procedure. By subjecting a gas or liquid that produces plazma to a strong electric field, this device produces a plazma medium. The material to be cleaned is subsequently subjected to an impact from this plasma. The following are some of the surface impacts of plasma: Plasma with the ability to ionize molecules on a material's surface and produce positive and negative ions is known as ionization. Surface residues and contaminants can be affected by these ions and removed. Plazma that can initiate chemical reactions to etch the material's surface is called etching. Etching is a technique that can be used to remove residues, oxidation layers, and new surface structures. Plazma that can activate a material's surface to improve compatibility with later procedures, including film coating or material bonding, is known as surface activation. Among the many benefits of plasma cleaning are the following: it doesn't require the use of harsh chemical cleaners, which helps to protect the environment and keeps users safe. the capacity to precisely and reliably clean intricate or finely textured surfaces. Capacity to remove contaminants with a high surface adherence. does not alter the fundamental characteristics of the material after cleaning. Numerous industries, including information technology, healthcare, electronics, optics, and manufacturing, use plasma cleaning.

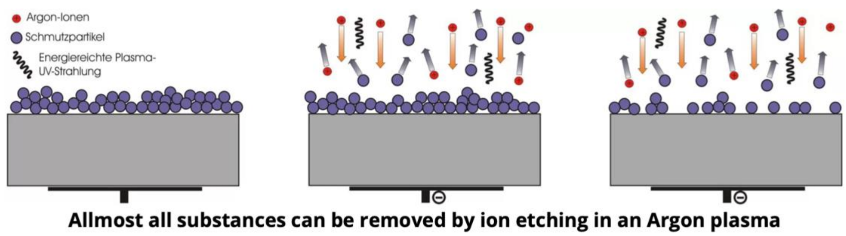

FIGURE 1
PLASMA CLEANING PROCESS OF DMA PRODUCTS

Process 2 (Injection Mold): Using plastic injection processes, the injection mold stage of production creates plastic products or parts out of plastic ingredients (Figure 2). Typically, this procedure entails the following steps: First, a plastic injection mold is developed according to the specifications of the finished product. The plastic material chosen and ready for the plastic injection process is known as material preparation. Plastic is injected into a mold after being melted into a liquid by a machine. This process is known as plastic injection. To guarantee that the resin fills the shapes and grooves on the mold and contacts the entire surface, high pressure is applied. Cooling and demolding is the process of lowering the temperature to cool and harden the plastic that has formed in the mold. Subsequently, the plastic component is removed by opening the mold. The final step of finishing involves inspecting the plastic parts, trimming any surplus material if needed, and sealing any seams or cracks. In the plastics business, the injection mold method is a popular manufacturing technique used to produce a wide range of plastic products, such as home appliances, automobile parts, electronics, and many more.

For the injection mold process to function properly and be of high quality, a number of critical requirements must be satisfied. An essential component of the injection mold process is temperature. In order to guarantee that the resin melts completely and uniformly and that the part cools down enough after injection to solidify and come out of the mold, the temperature must be properly regulated. To ensure that the resin contacts the entire mold surface and completely fills the grooves and shapes, pressure is applied during the plastic injection process. To ensure that the resin is firmly pressed and that the finished product is free of gaps or cracks, the pressure must be regulated suitably. During which the resin is injected into the mold and maintained under pressure is known as the injection time. This duration needs to be adjusted to give the resin enough time to fill the mold evenly and to ensure that it cools and solidifies before the mold is opened. Another crucial element is the caliber of the plastic that is injected into the mold. The resin needs to be suitable for the end application in terms of ductility, hardness, and chemical resistance. It is important to properly design the mold to make sure it has the right amount of depth, grooves, and shape to yield the desired finished product. Additionally, the material used to make the mold needs to be able to tolerate high temperatures and pressures. The particular application and the requirements of the finished product determine these and many other elements. To get the greatest outcomes, the injection mold process is a complicated one that needs to be strictly controlled and adjusted technically.

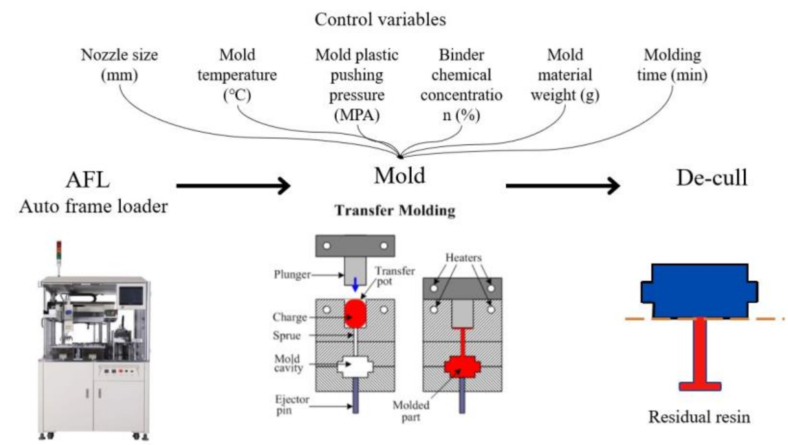

FIGURE 2
DMA INJECTION MOLD PROCESS

Process 3 (Final inspection by computer vision):
There are 4 main types of waste products generated after the injection mold process. Defect type 1 is a Split layer defect (Figure 3), occurring at a rate of 20% (1000/5000 pcs). Defect type 2 is a Flat wire defect (Figure 4), occurring at a rate of 4% (200/5000 pcs). Defect type 3 is Void defect (Figure 5), occurring at a rate of 0.2% (10/5000 pcs), and Defect type 4 is Corrugated Plastic defect (Figure 6), occurring at a rate of 0.6 % (30/5000 pcs). To ensure the quality of products delivered to customers, the company has invested in purchasing inspection machines using the computer vision method (Figure 7).

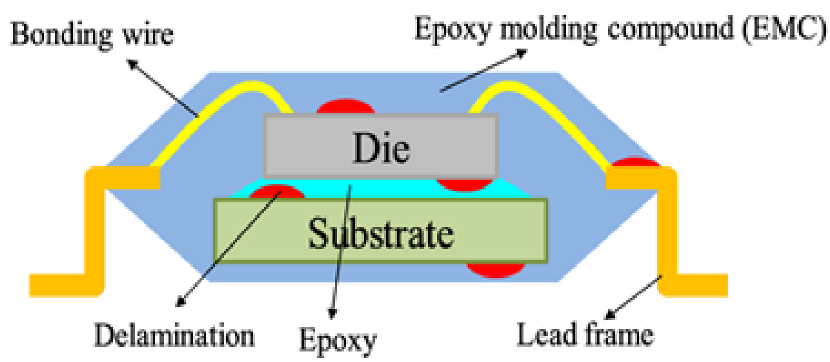

FIGURE 3
SPLIT LAYER DEFECT

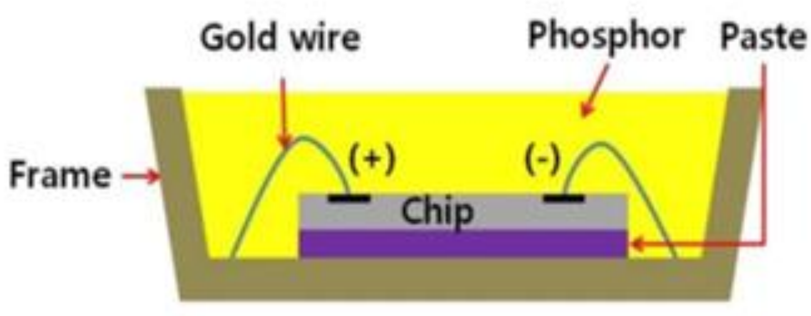

FIGURE 4
FLAT WIRE DEFECT

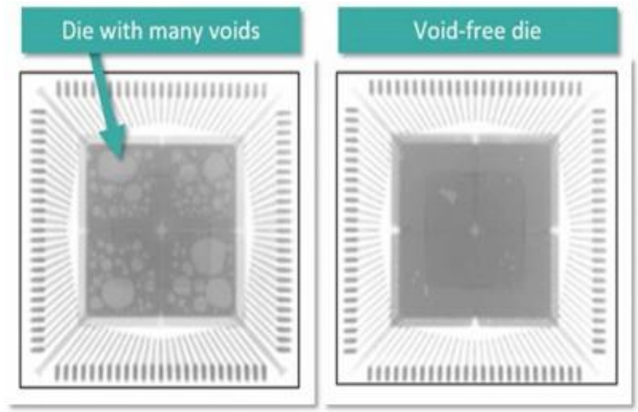

FIGURE 5
VOID DEFECT

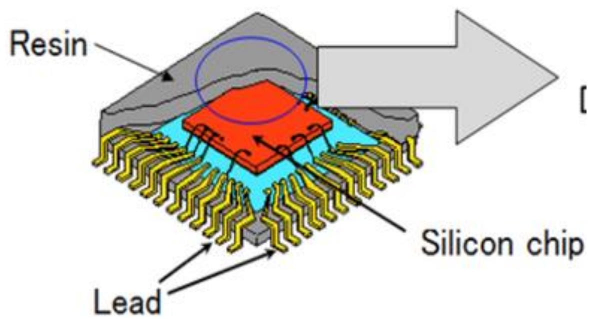

FIGURE 6
CORRUGATED PLASTIC DEFECT

FIGURE 7
ACTUAL USING COMPUTER VISION MACHINE

Computer vision is the study of how computers can "see" and comprehend images and videos. It is a subfield of artificial intelligence (AI) and computer science. Computer vision can be used to automatically examine and assess the quality and features of products based on pictures or videos during product inspection. By examining product photos or videos and comparing them to predefined quality standards, computer vision quality testing can be used to assess a product's quality. Computer vision algorithms are capable of identifying scratches and other product flaws. Product dimensions can be measured by computer vision dimensional measurement, which involves processing images to calculate the lengths, areas, volumes, and distances between product components. Computer vision can be used for product identification, allowing products to be recognized and categorized from pictures or videos. It is possible to train algorithms to identify distinguishing characteristics of products and group them into distinct groups. Product component location and assembly can be inspected using computer vision positioning and assembly inspection. In order to make sure that the components are assembled in the proper orientation and position, algorithms can analyze photos and calculate the position and rotation of individual components.

II. DMA injection mold process experience

This research article focuses on optimizing the injection mold process. To ensure the durability of the adhesive on the surface of the DMA product, the plasma cleaning process ensures the removal of blemishes and removes dirt from the product under 2 gauses. Figure 2 shows six conditions that impact the injection mold process. These conditions impact the injection mold process and give rise to the four main types of defects as above. Types of chemicals with corresponding density components used in the DMA production process at the injection mold process (Table I) and injection mold process testing equipment and quality assessment measurement equipment production process and product quality are presented in Table II.

TABLE I
CHEMICALS USED IN EXPERIMENTAL RESEARCH

Chemicals	Concentration	Unit
Nickel sulonate	120%	Kg
Nickel chloride	88%	g
Boric acid	25%	g
Amino sulfonic acid	25%	g
Nickel carbonate	45%	g
Nickel anode	90%	Kg
Fluorinated anionic surfactant	35%	Lit

TABLE II
EQUIPMENT USED IN EXPERIMENTAL RESEARCH

Equipment	Model
Ph Tester	PH-101
Heating magnetic stirrer	MH-1
Electric microscale	GF2000
Power supplier	LPS-301
Interfacial tension meter	K9-MKI
Contact angle meter	MODEL 683
Ultrasonic cleaning machine	L-900
Optical microscope	MM-40

CAUSE-AND-EFFECT DIAGRAM FOR QUALITY OF THE DMA INJECTION MOLD PROCESS

Fishbone diagrams are used in cause and effect analysis, based on the 5 whys analysis method to find the causes that give rise to a particular problem [18]. Cause and effect analysis, invented by Ishikawa in 1952, is widely utilized in manufacturing plants in Japan and globally [19]. Typically, the team implementing continuous quality improvement in the factory proposes a cause and effect diagram, implemented with arrows to analyze the root cause of the arising problem.

In this study, the product quality improvement team proposes to use a cause-and-effect analysis chart to analyze errors that give rise to defects in the DMA injection mold process (Figure 8, Figure 9, Figure 10). The causes listed in the cause and effect diagrams are used as input for technical factors to control factors that give rise to defects in the injection mold process such as nozzle size conditions. (mm), Mold temperature (℃), Mold plastic pushing pressure (Mpa), Binder chemical concentration (%), Mold material weight (g), and Molding time (min). From the above conditions, if the conditions with optimal parameters are not guaranteed, 4 main defects will arise Split layer defect, Flat wire defect, Void defect, and Corrugated Plastic defect.

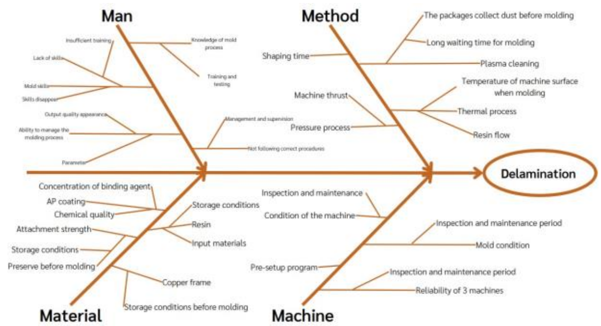

FIGURE 8
CAUSE-AND-EFFECT DIAGRAM OF THE DELAMINATION

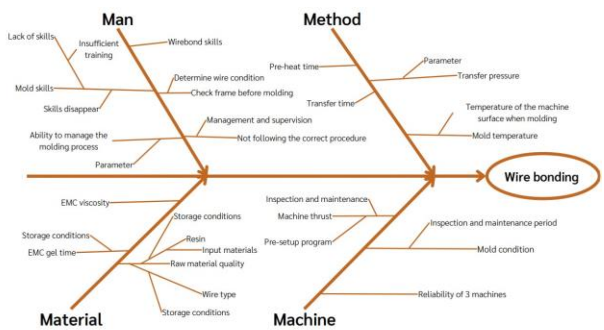

FIGURE 9
CAUSE-AND-EFFECT DIAGRAM OF THE WIRE BONDING

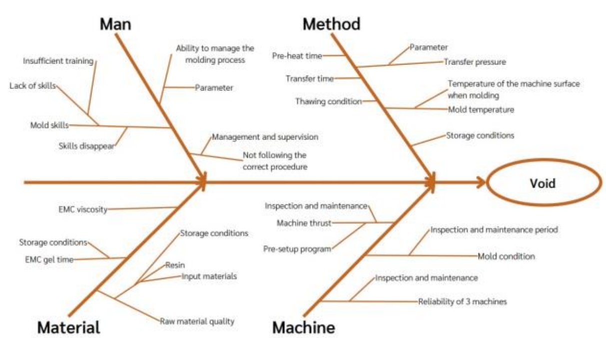

FIGURE 10
CAUSE-AND-EFFECT DIAGRAM OF THE ELECTROFORMING PROCESS

OPTIMIZING PROCESS PARAMETERS BY THE TAGUCHI METHOD

The Taguchi method is considered the best method for optimal implementation of finding optimal conditions in production processing, contributing to improving product quality, production process quality, and improving productivity. The orthogonal grids in the Taguchi method help reduce noisy parameters in experimental studies to create the best conditions for the experimental parameters of the Taguchi method (Table III). In addition, the orthogonal array also creates experimentally balanced levels compared to the Signal to Noise (S/N) index based on the logarithmic formula to improve the optimal level, creating analytical and predictive results. Experimental results are better. The "Signal" value represents the average value of the output level target, and the "Noise" value is the unwanted noise levels. The S/N ratio is calculated for the value used to evaluate the optimization level in the Taguchi experimental study.

S/N values follow the evaluation that smaller is better (Eq. 1).

$$\frac{S}{N} = -10 \times \log_{10}\left[(1/n) \times \sum (y_i^2)\right] \tag{1}$$

S/N values follow the evaluation that larger is better (Eq. 2).

$$\frac{S}{N} = -10 \times \log_{10}\left[(1/n) \times \sum (1/y_i^2)\right] \tag{2}$$

Where, n: number of experiments, y_i: results of the ith experiment.

TABLE III
OPTIONS FOR SELECTION OF ORTHODONTIC CODE IN THE TAGUCHI METHOD

Orth	Exper no.	Max no. of parameters	Levels			
			2	3	4	5
L4	4	3	3			
L8	8	7	7			
L9	9	4		4		
L12	12	11	11			
L16	16	15	15			
L’16	16	5			5	
L18	18	8	1	7		
L25	25	6				6
L27	27	13		13		
L32	32	31	31			
L’32	32	10	1		9	
L36	36	23	11	12		
L’36	36	16	3	13		
L50	50	12	1			11
L54	54	26	1	25		
L64	64	63	63			
L’64	64	21			21	
L81	81	40		40		

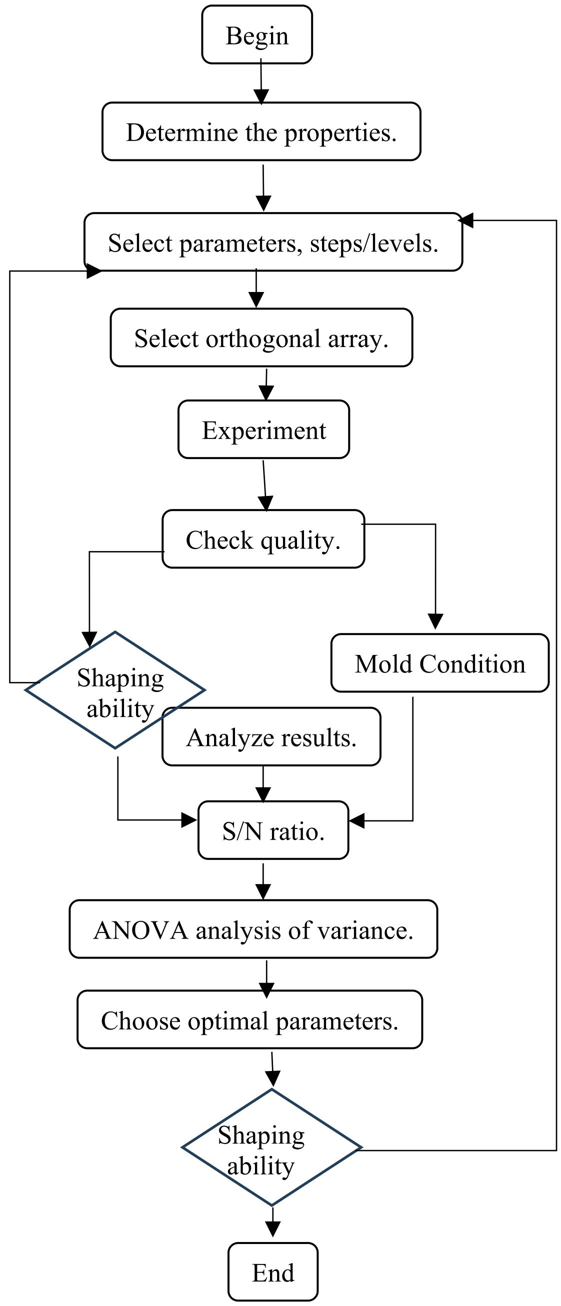

FIGURE 11
TAGUCHI OPTIMIZATION FLOW CHART

Choosing the right and appropriate independent variables in the orthogonal array brings optimal results in the Taguchi method and helps the Taguchi method give better results than other statistical methods. Correct selection of independent variables not only helps reduce the number of experimental evaluations but also ensures that no value is lost in the Taguchi experiment, improving the accuracy of Taguchi in performing optimization without being affected by surrounding interference factors. The Taguchi method used in optimizing Injection conditions at the Mold machine is carried out according to the flow chart (Fig .10).

In this study, quality engineers at the company applied the Taguchi method to approach [20] and analyze parameters affecting the Injection mold process of DMA products, optimizing Injection mold conditions. to bring about results in reducing production time improving product quality, improving productivity, and enhancing customer satisfaction. Experimental experiments using the Taguchi method are performed in a simple way. However, until now, quality engineers have not really paid attention to and used Taguchi to analyze and optimize the production process.

I. Experimental Design

The experimental model is built based on a parametric diagram (P diagram) [21] with impact parameters such as control parameters and disturbance parameters (Figure 12). The value meets the output of the experimental research model which is the DMA value, affected by control parameters such as nozzle size (mm), Mold temperature (℃), Mold plastic pushing pressure (Mpa), Binder chemical concentration (%), Mold material weight (g), and Molding time (min). The value of the control element has a set value (Tab. 4). The 6 control parameters are divided into 3 levels, but some of them contain 2 levels that are specifically set according to the control conditions of the processing machine and the technical requirements of the product. Factor A is Nozzle size (mm) which has 3 levels with corresponding values of 8.5, 8.6 , 8.7. Factor B is Mold temperature (℃) with 3 levels corresponding to values in order from level 1 to level 3 which are 195, 200, 205. Factor C is Mold plastic pushing pressure (Mpa) has 2 levels corresponding to 2 values from level 1 and level 2 are 10.0, 10.5. Factor D is Binder chemical concentration (%) with 3 levels with values from level 1 to level 3 respectively 70, 80, 90. Factor E is Mold material weight (g) with 3 levels with 3 values respectively from Level 1 to level 3 are 12, 12.5, 13 respectively. Factor F is Molding time (min) has 3 levels with the corresponding values from level 1 to level 3 being 13, 15, 17 respectively.

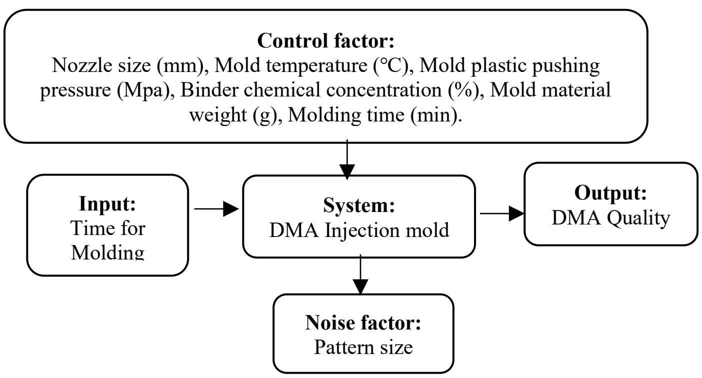

FIGURE 12
PARAMETER DIAGRAM

TABLE IV
CONTROL FACTOR AND LEVELS

No.	Description	Level 1	Level 2	Level 3
A	Nozzle size (mm)	8.5	8.6	8.7
B	Mold temperature (℃)	195	200	205
C	Mold plastic pushing pressure (Mpa)	10.0	10.5	---
D	Binder chemical concentration (%)	70	80	90
E	Mold material weight (g)	12	12.5	13

F	Molding time (min)	13	15	17

*Indicatior the initial design level

In Table IV, the results of the control factors include 1 factor with 2 levels and the remaining 5 factors with 3 levels. The degrees of freedom for this experimental study are calculated as 11 (=1+25). Therefore, the appropriate orthogonal network for the study is L18 (21*37), details of the variables in the orthogonal network are shown in Table V. Factor C has 2 levels so it is arranged in the first position of the network. Orthogonally, the control factors A, B, D, E, and F have 3 levels and are arranged in the following order respectively from the 2nd to the 6th column. Each experimental study is repeated at the same level according to the corresponding orthogonal network, with each iteration being performed 4 times for each level in the orthogonal network.

TABLE V
CONTROL FACTORS AND LEVELS IN L18 (21*37)

No.	C	A	B	D	E	F
1	1	1	1	1	1	1
2	1	1	2	2	2	2
3	1	1	3	3	3	3
4	1	2	1	1	2	2
5	1	2	2	2	3	3
6	1	2	3	3	1	1
7	1	3	1	2	1	3
8	1	3	2	3	2	1
9	1	3	3	1	3	2
10	2	1	1	3	2	2
11	2	1	2	1	3	3
12	2	1	3	2	1	1
13	2	2	1	2	3	1
14	2	2	2	3	1	2
15	2	2	3	1	2	3
16	2	3	1	3	2	3
17	2	3	2	1	3	1
18	2	3	3	2	1	2

II. Description of Experiment and Data Analysis

The values calculated in the Taguchi method are calculated as follows:

- Computation of Signal-to-Noise (S/N) Ratio

The Taguchi experimental analysis values are shown in detail in Table VI. The influence values of the noise factor calculated by the value according to the S/N ratio formula are shown in detail in Table VII and the relationship Experimental analysis of the control parameters is shown in Figure 13. The response values in the experimental study are analyzed and presented in detail in Table VIII. The diagram presents the responses of the parameters control is shown in Figure 14 and the optimal design values are presented specifically in Table IX.

TABLE VI
EXPERIMENTAL STATUS

							M1	M2	M3	M4	M5	M6
							26	26	36	36	48	48
	C	A	B	D	E	F	N1	N2	N1	N2	N1	N2
1	1	1	1	1	1	1	0.85	0.83	0.90	0.94	1.04	1.03

2	1	1	2	2	2	2	0.88	0.85	1.02	0.99	1.16	1.15
3	1	1	3	3	3	3	0.94	0.91	1.15	1.15	1.23	1.13
4	1	2	1	1	2	2	0.82	0.84	0.95	0.95	1.06	1.02
5	1	2	2	2	3	3	0.89	0.82	1.07	1.06	1.19	1.18
6	1	2	3	3	1	1	0.92	0.92	1.04	1.02	1.18	1.16
7	1	3	1	2	1	3	0.88	0.87	1.0	0.98	1.12	1.08
8	1	3	2	3	2	1	0.93	0.93	1.08	1.05	1.19	1.17
9	1	3	3	1	3	2	0.87	0.87	1.0	0.99	1.11	1.09
10	2	1	1	3	2	2	0.95	0.93	1.09	1.08	1.20	1.20
11	2	1	2	1	3	3	0.88	0.83	1.03	0.95	1.09	1.09
12	2	1	3	2	1	1	0.86	0.87	1.06	1.04	1.12	1.12
13	2	2	1	2	3	1	0.81	0.82	1.05	1.03	1.13	1.14
14	2	2	2	3	1	2	0.89	0.94	1.0	1.05	1.12	1.12
15	2	2	3	1	2	3	0.80	0.81	1.05	0.99	1.09	1.14
16	2	3	1	3	2	3	0.80	0.80	0.98	0.99	1.09	1.09
17	2	3	2	1	3	1	0.82	0.83	0.97	0.98	1.08	1.08
18	2	3	3	2	1	2	0.85	0.84	1.05	1.04	1.14	1.09

TABLE VII
RESPONSE TABLE TO SIGNAL TO NOISE

Signal to Noise						
	C	A	B	D	E	F
1	-14.78	-14.98	-15.93	-16.09	-15.99	-15.82
2	-15.46	-15.32	-15.89	-15.89	-15.98	-15.78
3		-15.98	-14.99	-15.90	-15.87	-16.09
S/N Contrast	0.29	0.03	0.75	0.77	0.89	0.81
Rank	5	6	4	3	1	2

FIGURE 13
RESPONSE GRAPH TO SIGNAL TO NOISE

TABLE VIII
RESPONSE TABLE TO SIGNAL

Mean						
	C	A	B	D	E	F
1	0.02187	0.02176	0.02136	0.02435	0.02019	0.02134
2	0.02318	0.02317	0.02091	0.02341	0.02134	0.02091
3		0.02521	0.02091	0.02314	0.20192	0.02132
S/N Contrast	0.00045	0.00031	0.00012	0.00213	0.00102	0.00123
Rank	5	6	4	1	2	3

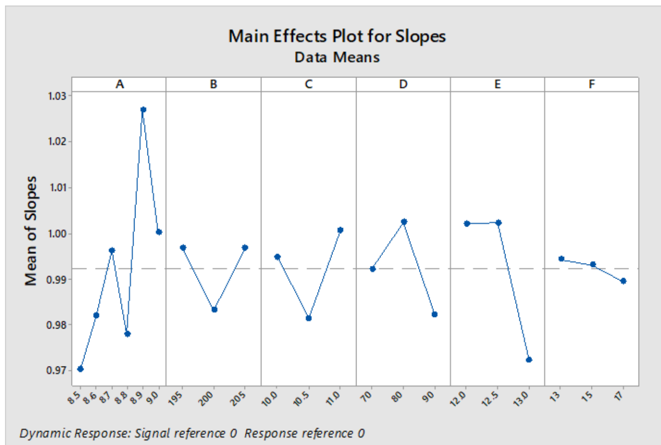

FIGURE 14
RESPONSE GRAPH TO SIGNAL

TABLE IX
OPTIMAL DESIGN

No.	Description	Level
C	Nozzle size (mm)	C2
A	Mold temperature (°C)	A3
B	Mold plastic pushing pressure (Mpa)	B2
D	Binder chemical concentration (%)	D2
E	Mold material weight (g)	E3
F	Molding time (min)	F3

- The initially designed S/N values are calculated as follow $S/N_{initial}$ and $S/N_{Optimial}$.

$$S/N_{initial} = \bar{C}_1 + \bar{A}_3 + \bar{B}_2 + D_2 + \bar{E}_3 + \bar{F}_3 =$$
$$= (-15.23) + (-15.83) + (-14.98) + (-15.02) + (-15.23) + (-15.83) = -15.45 \quad (1)$$
$$S/N_{Optimial}\ \bar{C}_1 + \bar{A}_3 + \bar{B}_2 + D_2 + \bar{E}_3 + \bar{F}_3 =$$
$$= (-15.65) + (-15.23) + (-14.09) + (-15.67) + (-15.45) + (-15.24) = -13.09 \quad (2)$$

The initial parameters configured for the experimental study included C2 A3 B2 D2 E3 F3, and these parameters were optimally configured after implementing the Taguchi experimental design. The optimal improvement level of the Taguchi experimental study is 2.36 (=(-15.45)+(-13.09). The optimal parameters are shown in detail in Table X.

TABLE X
PREDICTION RESULT

Result	S/N ratio
Initial design	-15.45
Optimal design	-13.09
Gain (Db)	2.36

III. Experimental Verification

The experimental re-evaluation of the results of the optimal parameter levels after the Taguchi experimental design, the experimental level value is 2.37 dB (=(-13.09)+(-15.46). This result shows the results Design research gives optimal results. At the same time, the analysis results show that the reliability and sensitivity values are improved satisfactorily, the results are shown in Table XI.

TABLE XI
EXPERIMENTAL VERIFICATION RESULT

Result	S/N ratio
Initial design	-15.46
Optimal design	-13.09
Gain (Db)	2.37

CONCLUSION

DMA injection mold design and implementation is done based on the experience and skills of the injection mold machine operator. This research paper results in a new and different approach compared to current implementation. The author uses cause and effect diagrams to identify important factors in experimental research. Next, the author uses the model to determine process parameters to design the Taguchi experiment. After specifically determining the parameters of the DMA injection mold process, product quality is significantly improved, productivity is increased and customer satisfaction is enhanced.

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