

## Research Article

# Simulation Process of Injection Molding and Optimization for Automobile Instrument Parameter in Embedded System

S. Ramesh <sup>1</sup>, P. Nirmla <sup>2</sup>, G. Ramkumar <sup>2</sup>, Satyajeet Sahoo <sup>3</sup>, G. Anitha <sup>2</sup>,  
A. K. Gnanasekar <sup>4</sup> and J. Isaac JoshuaRamesh Lalvani <sup>5</sup>

<sup>1</sup>Department of Electronics and Communication Engineering, Sri Shakthi Institute of Engineering and Technology, Coimbatore-641062, Tamilnadu, India

<sup>2</sup>Department of Electronics and Communication Engineering, Saveetha School of Engineering, SIMATS, Chennai 602 105, Tamil Nadu, India

<sup>3</sup>Department of Electronics and Communication Engineering, Vignan's Foundation for Science, Technology and Research (Deemed to be University), Vadlamudi, Guntur, Andhra Pradesh 522213, India

<sup>4</sup>Department of Electronics and Communication Engineering, Rajalakshmi Institute of Technology, Chennai, Tamilnadu, India

<sup>5</sup>Department of Mechanical Engineering, Faculty of Mechanical and Production Engineering, AMIT, Arbaminch University, Arba Minch, Ethiopia

Correspondence should be addressed to S. Ramesh; srameshece@siet.ac.in and J. Isaac JoshuaRamesh Lalvani; isaac.jrl@amu.edu.et

Received 23 July 2021; Accepted 7 August 2021; Published 30 August 2021

Academic Editor: Mohanavel V

Copyright © 2021 S. Ramesh et al. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

The automobile instrument is the indispensable item that is essential to keep the driver conversant of the process of the engineer and the other system. There are different parameters involved in the automobile instrument, which requires a different process involved in creating the automobile parameter. This research is designed to show the simulation development of injection molding and optimization of automobile instrument parameters using different optimization techniques. In this paper, Taguchi Orthogonal parameter design and particle swarm optimization (PSO) are used to measure the shrinkage volume rate and warpage amount rate. Most of the studies are designed to calculate the reduction and warpage for the gate location and glass material. The Taguchi orthogonal design contains five different parameters which are inversely proportional to each other. Hence, by optimizing those parameters, the injection molding procedure is passed out. In this research, the paper is designed to process the injection molding for the automobile instrument parameter using optimization techniques.

## 1. Introduction

Injection molding is one of the rapid methods commonly used in the plastic industry and then widely used to create automobile parts. Automobiles are the important item used to keep the driver updated with the process happening in the engine and on another system [1]. The injection molding process is used to design the automobile instrument in different shapes and weights. Due to their inimitable properties like insubstantial, low cost, increase padding, and reasonable deterioration, confrontation injection molding is used in the manufacturing of automobile instruments. Based

on the current situation, to reduce the manufacturing cost and weight of the vehicles like cars and buses, plastic parts were used in the large share. Numerous faults occur due to the short setting of ending flexible items. Therefore, it is important for the stimulation and analyses of every element in the inoculation procedure [2]. This has to be done before manufacturing the elastic portions to attain the enhanced injection molding procedure parameter, control defects, checking of artefact value, and advance efficiency manufacturing.

Most of the injection molding techniques use Minitab software to simulate plastic. At present, to design the whole

injection molding process, Minitab Insight is applied, and this also includes the drift, padding compression, warpage, reduction, cavitation, and strength alignment [3]. The software helps in finding the faults in the elastic parts that could be predicted, and this could also develop different plastic parts through the molding process. The parameter manufacturing using injection molding can be optimized. This could further reduce the manufacturing cost and the manufacturing productivity could be improved. This mainly avoids the defects like bulb welding marks, reduction holes, and distortion in the plastic parts due to excessive warping [4].

To obtain better process parameters for individual products, the engineer must be able to rely on his overall expertise to apply a test-error method or a Taguchi approach. Numerous experiments were done to achieve the suitable parameter combination; hence, both methods are considered time-consuming methods. To seek out the initial process in parameter setting Taguchi method requires the signal to noise ratio (S/N), and a relatively great effort is needed [5]. Mostly Taguchi orthogonal array table is used for the injection molding, and to investigate the optimal process, parameter injection extrusion molding is used. Important factors such as melting temperature, injection speed, mold temperature, and filling pressure are also studied. Grey level correlation analysis and response data were carried out in the Taguchi orthogonal test in the optimization process. To conduct the injection molding experiment in the Taguchi orthogonal method, four factors and three levels through the statistical design method are used. During the setting of final optimal process parameters, the optimization problem occurs, and this is mainly created in the production industry. The important step involved in the optimization procedure parameter during injection molding is the quality improvement of molded items or parameters [6]. This process is often handled by the experienced engineer, and reference handbook was given to them and parameter was improved, and trails were made to check the fine-tuning, and then the error is checked using the Taguchi design method. The experienced molding operator is needed for better operation, and this method is cost-efficient, and it takes a lot of time to operate specifically with a new application or new resins [7]. It is stated that by using trial and end process, the optimal process parameter actual value can be verified correctly. By using the Taguchi parameter design method, the specified process parameter can only be found, and the discrete setting value is included in the process parameter.

The quality of the molded plastic product could be affected by the injection molding and then by defining the parameter setting procedure. Production problem is caused due to the unsuitable process parameter, and competitive price advantage is reduced, and this could further decrease the profit of the company [8]. The four stages are included in the plastic injection molding process. They are filling, padding, cooling, and remolding. Different control process parameter has been used in the previous research and those parameters were used for injection-molded plastic and they are determined by the optimal initial process [9]. This includes the butter flask lid and single quality considerations.

To determine the preliminary process parameter settings for the injection-molded plastic parts, four control process parameters were used and this is maintained with a thin shell feature and with the influence of the tractable control process parameter. Hence, different research deals with the optimization of a parameter using different research techniques, and they failed to optimize the problems caused during the injection molding process.

In this search, the volume removal and amount of warpage are calculated by optimizing the issue created during injection molding. By combining the Multiple-Input Multiple-Output (MIMO) with the Taguchi design parameter method, the problems during the various factors and the process parameter are reduced; along with it, particle swarm optimization is used to observe and determine the shrinkage and the warpage amount of correct accuracy. Thus, the problem in the optimization of the automobile instrument could be reduced. From the survey, it is observed that the previous methods lack testing methods and consume more time during implementation in molding process.

*1.1. Literature Survey.* With the problem of ecological trash and power exhaustion in recent years, an innovative control tech that recovers the routine of the motor car has been sought. The method for constructing a reactive surface is proposed by [2]. It expresses the method for optimizing control parameters for the car engine. This document defines a method to construct the response area model and a method to optimize the control parameters for the automotive diesel engine. It progresses a model-based monitoring system and a design-based early expansion technique. The projected technique for constructing the response surface model is capable of efficiently defining the numerous regulator limitations against the typical value, like petroleum ingesting and emissions. The optimization method of control parameters can be fast and efficient and can compute the ideal control restrictions to optimize assessment elements such as petroleum ingestion and emissions based on the model.

Kaveh and Rad [9] proposed a method to describe analysis and design called a hybrid genetic algorithm and optimization of the particle swarm for the force method. The computer inconveniences of existing numerical methods have forced researchers to rely on heuristic algorithms. Heuristic methodologies are powerful in resolving optimization problems. While these methods are approximate, they do not need to be derived from objective function and limitations. Here, we have a scalable algorithm based on hybrid genetic algorithm (AG) and particle swarm optimization (PSO), denoted by HGAPSO [4]. It is an evolutionary algorithm based on a hybrid genetic algorithm (GA) and particle swarm optimization (PSO), referred to as HGAPSO. The appropriateness of the algorithm is compared with both the genetic algorithm and the PSO in the overall strategy, an example of effectiveness and superiority, especially for executives who are more redundant.

The well-formed and tested Artificial Neural Network matrix has been attached with the enhanced PSO algorithm as an ANN-PSO fusion to optimize the parameters of the

inoculation molding process. The work in [10] proposed the injection molding process for the optimization of Bi-Aspheric lens and used the hybrid Artificial Neural Network (ANN) and particle swarm optimization (PSO) to optimize the problems created during the molding process. The PSA network (7-13-6) was developed and tested using tentative data derived from arithmetic methodologies. The formed and tested ANN network was coupled with the improved PSO system as an ANN-PSO hybrid to optimize the parameters of the injection molding process. The injection system optimizes the molding process parameters achieved with the ANN-PSO hybrid algorithm legalized with researches that please the J. S. W. injection molding machine.

The design of injection mold and the automotive panel optimization research paper is proposed by [3]. In this document, an automotive panel for analyzing injection molding processes and matrix design is presented. Injection molding parts on the instrument panel performs investigation to regulate the area for system synchronization. The injection molding components carry out a flow analysis of the mold to determine the probability, and the matrix timing system and the gas injection molding process are optimized. Thus, high quality spraying products are obtained. In practice, CAE technology for plastic mold design and plastic molding has been shown to play a major role.

Injection molding parts on the dashboard through mechanical examination and process to regulate the separation zone, synchronization systems. Injection molding optimization design is designed by (Ren and Zhang) based on particle swarm optimization and a genetic algorithm for a cooling system. In this article, a hybrid approach combining PSO with gene algorithms (GA) is developed to achieve the optimal design of the cooling system. Using the finite element method (FEM) and the finite difference method (FDM), the numerical simulation of the cooling process is conducted for part of the injection mold. On the basis of the limited element method and the limited difference method, a numerical simulation of the cooling process is carried out for a portion of the injection mold. An example of an injection cooling system illustrates how effective this approach is.

The process of filling the elastic melts into the shell of the injection mold for the loop in the interior embellishment of the automobile has been simulated based on Minitab software [11]. The best door slot has been reached in this work, which ensures that the product can be refilled. In addition, the optimal design of the door location and the number of plastic products were reviewed. Based on the qualified analysis of the door, the on its own door is greater than the double door in the function of the spreading of the air concise and the welding line. In short, the rational number of doors and the location guarantee the correct operation of the injection mold, thereby reducing the manufacturing cost.

## 2. Materials and Method

To determine the automotive instrument parameter, 3D model parts must be drawn up for the parameter to be designed. This is the major step for injection molding. In this method, optimal gate position and the simulation of the

gating system are determined along with the cooling system. To design the 3D model of automobile instrument care, a drawing instrument is used [5]. Let us consider the certain dimension, length, and weight of an automobile instrument to be molded into a parameter. The instrument designed for the automobile must be compatible with the bottom circuit board and top plate. Subsequently, during the casting process, the volume withdrawal rate and the warping of the part must be minimized. The following factors come into play in the injection molding procedure. Figure 1 shows the flow diagram for the injection molding process.

Through the Hooper, the plastic pellets are passed to the high-temperature injection barrel during the molding process. The pellets are intense, liquefied, and recreated into plastic and again turned into the tacky liquid stream, which is then injected into lower temperature. At high speed and pressure, the melted pellets are passed through the injection nozzle and then welded by the plunger or the screw. The molten plastic enters the cavity at high pressure and is also compressed. At this stage, it is possible to flow out of the cavity into the well and channel system. The artefact is released from the mold hollow after the cooling and forming are done.

- (i) Feeding: The hopper is fed by the pellets or powder
- (ii) Melting: In the barre, the plastic is heated, and it turns from solid pellets into the liquid stream, and this requires great plasticity
- (iii) Injection: By piston or by screw, the flux of molten plastic is pushed into the barrel and fills the cavity of the mold by means of the injection nozzle and the core and the passageway. This is known as an injection.
- (iv) Maintaining pressure: In the replenishment process, the molten material is pushed continuously by the diver or screw in the meantime due to the cooling of the molten material that shrinks inside. During this process, the complete structure is formed, and the texture of the product is created. This process is known as pressurization.
- (v) Cooling: The cooling process inside the mold generally refers to the entire process from the moment it occurs. In this process, the melted material at the door, which is completely solidified to the plastic patch is ejected from the mold cavity. But in fact, the cooling phase begins the moment the molten plastic enters the cavity. This covers the period from the end of the injection, from the pressure retention to the moment prior to the beginning of the mold release.
- (vi) Unmolding: Unmolding is allowed when cooled at a certain temperature, through which the plastic part is expelled from the mold by the ejectors.

*2.1. Process of Making Automobile Instrument by Reaction Injection Molding.* One of the most common techniques used in the design of automobiles instruments is Reaction Injection Molding (RIM). In this method, liquid reagents are

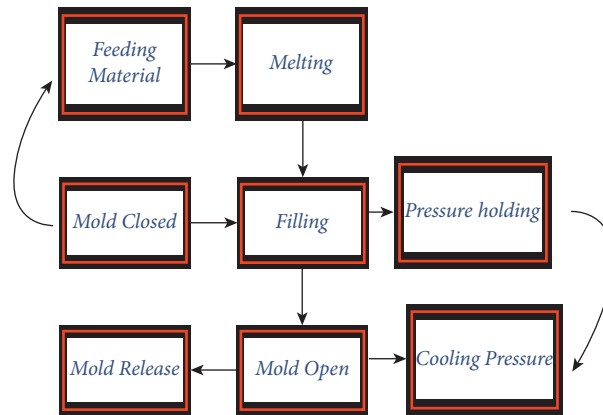


FIGURE 1: Injection molding process includes feeding and melting.

fed to the mold just before injection. This is followed by polymerization, which forms the plastic along with the molding. The polymerization process produces the material with the desired property and enhances the material property for reinforcement. Reinforcement loads are incorporated in any of the reagents and this is called enhanced reaction injection molding. Figure 2 represents the basic process of Reaction Injection Molding. In this process, to make a rapid polymerization reaction, a certain type of plastic is required, and they may be polyesters, epoxy, nylons, and vinyl monomers. Nonetheless, polyurethane is the most frequently used material. In this research to mold an automobile instrument parameter, the polyurethane and polystyrene are taken as the plastic resin and kept circulating in their separate system.

They are kept separate until they are ready to shed to the injection shot. Polyurethane and polystyrene were then added to the blend head and injected into the mold. Both the reactants in the separate system have low stickiness. The pressure injection is relatively low in the Reaction Injection Molding process. Comparing the conventional injection molding with reaction injection molding, the tightening force is the same for both molding processes. Even though the RIM process is mainly used to make the automobile instruments like a car bumper and body panels, in the RIM process, different materials can be used for the molding process due to the consequence of low injection pressure; they include aluminum and low copper metals [12]. Based on the research, aluminum is one of the best products for making automobile instruments due to its corrosion resistance, and the weight of the large mold parts is saved. Compared to injection molds, molds are less expensive. As the materials used in the RIM process are expensive, they need careful handling, and the particular product or the parameter must have the perfect finishing, and the surface finishing must be perfect and fine due to the expansion of the material. In the polymerization process, the surface of every detail must be reproduced during molding.

**Filling Time:** It is well-defined as the time needed to fill the whole cavity with the molten plastic and to analyze the

configuration of the software of the molten part like Minitab can be used.

**Flow Front Temperature:** The temperature of the intermediate material flow is defined as the flow front temperature; the certain node is filled with molten plastic. The temperature is also termed the intermediate temperature.

**Clamping Force:** Clamping force is defined as the maximum clamping force needed to exert the node.

**Welding Line:** The molded plastic parts must be ensured based on perfection, good surface, and appearance, so to ensure those appearances, the welding line length and number should be minimized. In the places of visible areas and stress concentration areas, the welding wires are not permitted.

Based on the above factors like Filling period, flow front temperature, clamping power, and welding stripe, a tabulation is made based on a certain assumption of a part as mentioned in Table 1.

**2.2. Design Using Taguchi Orthogonal Design.** For optimizing the process parameter for simple and robust technique, Taguchi method has been applied, and it is successfully used among the optimization technique [13]. According to Taguchi's design objectives, there are three different average square deviations calculated for the signal-to-noise ratio and which include better-the-nominal, better-the-large, and better-the-small. The research aims to optimize the warpage and shrinkage amount. The shrinkage and warpage value must be minimum rate, and thus, the S/N ratio of the smaller-the-better formula has to be chosen for optimizing the parameter rate, and hence the combination is obtained.

**2.3. Simulation of Automobile Instrument Part.** For the simulation process of automobile instrument, assume a cluster instrument and as said before, polypropylene (PP), is used as the resin material. The properties of the materials were taken from the database of Mold Flow software: the properties include melt density, mold temperature, melt point, material flowrate, and Poisson rate, and the value is presented in Table 2.



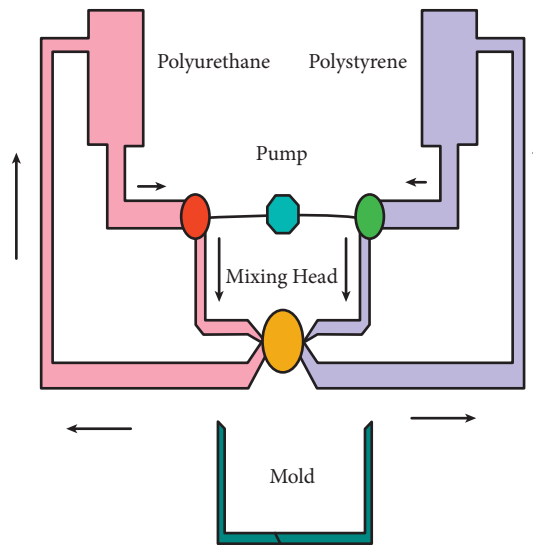


FIGURE 2: Basic process of reaction injection molding.

TABLE 1: Assumption for the automobile instrument based on four configurations includes filling period, temperature, power, and stripe characteristics

Filling period	Flow front temperature	Clamping power	Welding stripe characteristics
1.333	3.5	1060	The length is large and a greater number of pieces
1.381	12	807	
1.205	21.2	721.2	The distribution is reasonable and the smaller number of pieces
1.066	8.4	1070	

2.4. *Experimental Design.* At the first step, by using Taguchi orthogonal design, the analyses of finite element is carried out by implementing four constraints like material flow rate ( $FR_M$ ), mold point ( $T_M$ ), melt point ( $M_T$ ), and the injection pressure ( $P_I$ ) [14]. From the database of Minitab, the material properties are determined for the material flow rate, mold temperature, melting point, and based on the industry experiences, the injection pressure is calculated. Based on the analysis, the injection time is calculated, the maximum injection time is 4.557 (Sec), and the minimum time is 2.489 (sec). To determine the optimal level of parameters, the orthogonal design is used along with the four constrain such as injection time ( $T_I$ ), packing pressure ( $P_P$ ), packing pressure time ( $T_p$ ), and the cooling point ( $T_C$ ). In this, the injection time is the first step and followed by this, the packing pressure is done. After completing the packing pressure, the time is given for it, which is known as packing pressure time, and then finally a cooling point is given and the process gets completed.

According to the outcome of the analysis, the extreme warpage value of this part is 2.633 mm, stirring in the remote area of the doors. Figure 3 is created based on the 3D design of the Creo drawing tool and then by molding them, a dashboard of the automobile is designed. Automobile vehicles have faced a large problem in traffic management, so certain sensors were insulated in the automobile parameter to manage the traffic system [15]. In the above dashboard, the vehicle owner could communicate with the other vehicle owners. Certain settings include communication between

the server and third parties such as perambulation police, ambulance, and fire department. In communication between the vehicle and the vehicle, the owner involves certain factors like vehicle speed, fuel, and kilometer between the starting point to the destination which are directly reported to the vehicle owner either by voice or by screening the message [1]. It is necessary to update the active data of the vehicle even when they are not in use and when the automobile is far away from the user and involved workstation is used. In order to reduce the accident happening around high traffic area, the automobile parameter is embedded with a certain microcontroller that tracks the movement of the vehicle, spots the high traffic zone, and then gives direct information to the vehicle owners to avoid accidents. The embedded system works on the basic of BX-24 microcontroller and it also combines with exterior strategies. To store the basic information of the X operating system, a fast core processor with Read-Only Memory is used in the BX-24 system. This basic process consists of Read-Only Memory and Random-Access Memory about 400 bytes and electronically erasable programmable read-only memory of 32 Kilobytes and a timer with an I/O device. Digital pins were also present in the basic BX-24 system. Thus, this embedded unit helps to receive information about the vehicle moving around the traffic zone. These exterior devices like input and output ports could be used in the car door along with a sensor device to open, close, and lock the car door even away from the vehicle. To offer a complete monitoring of the system, the embedded system uses the user interface such as LCD and

TABLE 2: Assets of particle.

Properties	Value
Melt density (g/cm <sup>3</sup> )	0.87723
Mold point (°C)	66
Melt point (°C)	215
Material flowrate (g/5 min)	9
Poisson rate	0.3851

LED display and the interactive mode of work. This could help to evaluate the signal between traffic zone. The LCD and LED display could help to receive the data sent by the microcontroller. Some sensor sends beep sound to give an important message like alerts, break, begin, and emergency purpose. The interface element is used to control the sequence of the strings. The user database could be easily generated by the computer interface. To configure the final interface system, the user could use it after the completion of the final step sequence. Thus, the whole embedded processor works on the automobile instrument, specifically in locking and traffic management.

**2.5. Particle Swarm Optimization.** Particle Swarm Optimization (PSO) is a computational method that optimizes the problems in an iterative manner, which is used to improve the solution to the given measure of quality. To determine the importance of the constraints and influences, Particle Swarm Optimization is performed. By dividing the total variability into contributions based on each design parameter, the PSO result is carried out. This could also verify whether the altered level adjustment or experimental error causes any change in the observed variation in response. The sum of the square, degree of freedom, mean square, and  $F$ -test of significance is calculated using the PSO.

The improved form of PSO of fitness function states the error sum of square required, and it is defined by the following:

$$S = \sum_{m=1}^n (Z_{rm} - Z_{pm})^2. \quad (1)$$

Fitness function is stated as  $S$  and the required and the predicted value are represented as  $Z_{rm}$  and  $Z_{pm}$ , where  $m$  is the output parameter individually. There is  $n$  number of the output parameter. To optimize the injection molding process parameter, the Genetic Algorithm (GA) optimization technique is used along with the PSO. These optimized process parameters were compared to the best process parameters in the PSO. GA is used to generate high quality solutions to optimization and search problems. PSO is a computational method that optimizes the problems in an iterative manner.

**2.6. Design of Optimization.** However, many calculations and high costs will be incurred due to many factors if the whole aspect method has been employed. Nevertheless, numerous calculations and high costs will be incurred due to many factors if the full factor methodology has been used. In

this research, the Taguchi method was used to solve this problem. Firstly, an orthogonal network (OA) that provided sufficient information to form the inverse model using the minimum number of researches for the design of the condenser was built.

Finally, the information sets and MIMO were used to generate a model recitation the inverse affiliation between mechanized factors and a point-of-sale high point in specific locations. Figure 4 illustrates how the optimal plan is executed.

### 3. Results and Discussion

To run the experiment, the L27 Orthogonal array method is used. The wear characteristics response was measured. By retaining the Taguchi method, the optimized parameter is defined. To find the analysis variance and other necessary factors, L27 orthogonal Taguchi method is used. Using the orthogonal series, the analysis was systematized and the self-determined variables like temperature and distance sliding were noted.

**3.1. Variance of Analysis.** The variance of analysis is a decision-making tool and this is used to analyze the performance difference of the test conducted. By the squaring and estimation process, the variance of analysis is calculated, and error specific levels are measured. By using the following expression, the average test for the variance analysis is measured.

$$S_T = \sum_{n=1}^m (\beta_n - m_i)^2. \quad (2)$$

The influence of the processing parameter is influenced by the unique ratio of the sum of a square and the sum of deviation, and then they are processed by the parameter indices, where the total sum of squared deviation is represented as  $S_T$ , the total mean S/N ratio is defined as  $m_i$ , and the total number of experiments done in orthogonal array are defined as  $m$ , and the  $\beta_n$  is defined as the S/N experiment ratio. SNR for shrinkage volume and warpage amount is shown in Table 3.

The important feature of the warpage amount is cooling time and warpage amount is proportional to each other as the time of cooling increases, the warpage amount increase, and then it starts to decrease. The melt temperature is considered as the second effective feature, and it is about 25.30% of the warpage amount [16]. The warpage amount decreases rapidly as the melt temperature decreases. It is noted that a similar interpretation is found for the pressure

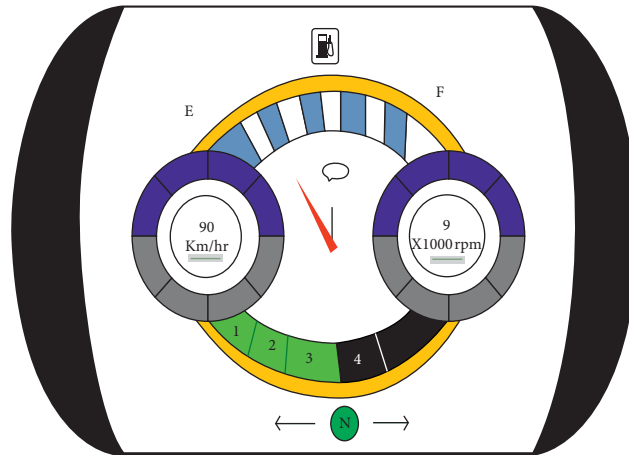


FIGURE 3: Automobile dashboard.

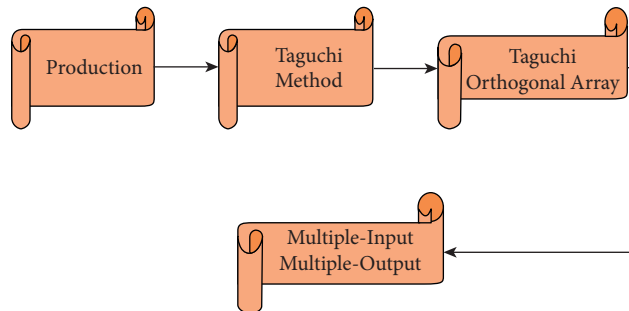


FIGURE 4: Optimization plan.

TABLE 3: Signal-to-noise ratio of shrinkage volume and warping amount.

Number of test	Signal-to-nose ratio of volume shrinkage rate and warping amount	
	Shrinkage rate	Warping amount
1	-20.688	-6.370
2	-19.255	-5.990
3	-18.607	-5.632
4	-17.775	-4.598
5	-22.100	-5.148
6	-17.450	-6.029
7	-16.584	-5.711
8	-17.741	-5.982
9	-21.591	-5.805
10	-21.980	-5.343
11	-16.845	-5.347
12	-17.690	-5.926
13	-21.600	-5.820
14	-16.970	-5.497
15	-17.350	-6.130
16	-19.390	-5.987
17	-21.970	-4.670
18	-16.880	-6.098
19	-21.970	-5.029
20	-16.880	-5.550
21	-16.910	-5.845
22	-21.580	-5.705
23	-21.900	-5.856
24	-18.024	-5.754
25	-18.351	-5.889
26	-20.590	-5.798
27	-18.438	-5.746

TABLE 4: Mean of SNR of shrinkage and warpage.

Objective optimization	Mean value	A*	B*	C*	D*	E*
Shrinkage rate	$J_1^*$	-18.671	-18.045	-19.360	-19.480	-21.340
	$J_2^*$	-18.952	-18.630	-18.720	-18.781	-19.750
	$J_3^*$	-19.260	-19.500	-18.990	-19.185	-17.774
	$J_4^*$	-19.300	-20.030	-19.055	-18.730	-17.335
	$Y^*$			-19.005		
Warping amount	$J_1^*$	-5.343	-6.048	-5.856	-5.550	-5.497
	$J_2^*$	-5.347	5.850	-5.754	-5.830	-6.130
	$J_3^*$	-5.92	-5.640	-5.889	-5.748	-5.987
	$J_4^*$	-5.820	-5.550	-5.798	-5.531	-4.670
	$Y^*$			-5.746		

TABLE 5: Variance result.

Objective optimization	Variance of source	Mean square of deviation	Degree of freedom	Mean square value	Degree of influence
Shrinkage rate	A*	0.355	3	0.075	
	B*	2.555	3	0.880	
	C*	0.215	3	0.075	
	D*	0.375	3	0.130	
	E*	10.400	3	3.468	
	SO	13.825	15		
Warping amount	A*	0.0065	3	0.0025	1.06
	B*	0.1550	3	0.0516	24.28
	C*	0.4044	3	0.1016	47.65
	D*	0.0915	3	0.0305	14.44
	E*	0.0816	3	0.0275	12.77
	SO	0.6365	15		

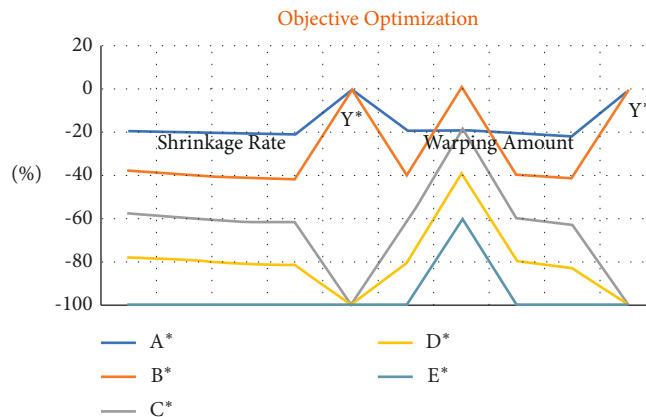


FIGURE 5: Objective optimization based on mean value.

TABLE 6: Final result of warpage and shrinkage amount based on Taguchi orthogonal array.

Index	Factor influence	Parameter combination	Shrinkage volume	Warping amount
Taguchi based warpage amount	$C^* > B^* > D^* > E^* > A^*$	$A^*1B^*1C^*2D^*4E^*4$	6.821	2.010
Taguchi based shrinkage rate	$E^* > B^* > D^* > A^* > C^*$	$A^*4B^*4C^*1D^*4E^*1$	12.70	1.780



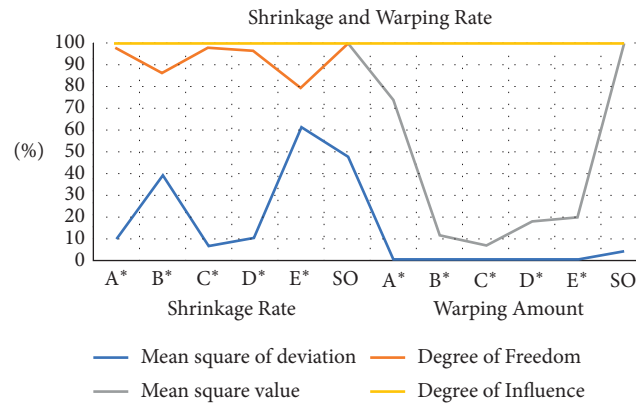


FIGURE 6: Result of variance.

of packing and packing time and this is about 15.33% and 12.66%.

Based on the Taguchi orthogonal test design, the influence degree of various molding parameters on volume shrinkage rate and warpage amount can be obtained. Accordingly, the optimal combination of molding parameters can be obtained to minimize the volume shrinkage rate and the warpage amount which is shown in Table 4.

Using the Taguchi orthogonal array method, the warpage and shrinkage volume is calculated from the above-mentioned analysis of finite elements and S/N ratio. Table 5 shows the variance result. Figure 5 is determined by using signal-to-noise ratio equation; warpage and shrinkage capacity are calculated [17].

Finally, the warpage and shrinkage volume amount of the automobile dashboard is calculated and the optimization of the automobile parameter is done using the Taguchi orthogonal array method. The signal-to-noise ratio is calculated using the above-mentioned expression and followed by the expression, the warpage and shrinkage volume is analyzed and represented in the graphical form [18, 19].

In Table 6, final result of warpage and shrinkage amount based on Taguchi orthogonal array is presented in which  $A^*$  denotes the mold temperature,  $B^*$  denotes the melt temperature,  $C^*$  denotes the cooling temperature,  $D^*$  denotes the packing pressure, and  $E^*$  denotes the packing time. The warpage and the shrinkage result depend on the following four-parameter: injection time, packing pressure, packing time, and cooling point. For three series of data, the following parameter is calculated and presented in Figure 6.

#### 4. Conclusion

In the present study, the four configurations are primarily proposed for injection molding and for the optimization of automobile parameters using the Taguchi Orthogonal Array method. By using the Minitab software, the numerical analysis is made. The analysis of filling time, flow front temperature, clamping force, and welding line is compared. From the result, it is shown that the filling time is about 1.055 seconds and the different flow front temperature is about  $7.4^\circ\text{C}$  and the clamping force is 1060 kN, the welding line number is low, and distribution is low for welding. The paper

mainly deals with the Taguchi Orthogonal Design as they help in reducing the factors of the injection molding system. As said before, the parameter like packing time, packing pressure, melt point, mold points are inversely proportional to each other, and when this optimization technique is used, they reduce the maximum temperature used in designing the mold. Specifically, the automobile parameter requires high temperature for melting and molding them, but by using the Orthogonal Array method, half the temperature and time are reduced and the defects in the parameter are found and changed by the particle swarm optimization. Hence, the paper clearly defines the simulation process of injection molding along with the optimization of automobile instrument parameters using the Taguchi Orthogonal Array design and Particle Swarm Optimization.

#### Data Availability

The data used to support the findings of this study are included within the article.

#### Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

#### References

- [1] A. W. Judge, "Automobile electrical instruments," in *Modern Electrical Equipment For Automobiles*, pp. 292–315, Springer, Berlin, Germany, 1970.
- [2] M. Ogawa, Y. Suzuki, H. Ogai, and J. Kusaka, "Development of method for construction of a response surface model and control parameter optimization method for automobile engine," *Transactions of the Society of Instrument and Control Engineers*, vol. 47, no. 10, pp. 501–510, 2011.
- [3] Z. Zhao, X. He, M. Liu, and B. Liu, "Injection mold design and optimization of automotive panel," in *Proceedings of the 2010 Third International Conference on Information and Computing*, pp. 119–122, Wuxi, China, June 2010.
- [4] M. Vishnuvarthanan, R. Panda, and S. Ilangovan, "Optimization of injection molding cycle time using moldflow analysis," *Middle-East Journal of Scientific Research*, vol. 13, no. 7, pp. 944–946, 2013.

- [5] L. Ren and W. Zhang, "Optimization Design of Injection Mold Cooling System Based on Particle Swarm Optimization and Genetic Algorithms," in *Proceedings of the 2011 2nd International Conference on Artificial Intelligence, Management Science and Electronic Commerce (AIMSEC)*, p. 5, Deng Feng, China, August 2011.
- [6] W.-C. Chen, M.-H. Nguyen, W.-H. Chiu, T.-N. Chen, and P.-H. Tai, "Optimization of the plastic injection molding process using the Taguchi method, RSM, and hybrid GA-PSO," *International Journal of Advanced Manufacturing Technology*, vol. 83, no. 9–12, pp. 1873–1886, 2016.
- [7] K. Shelesh-Nezhad and E. Siores, "An intelligent system for plastic injection molding process design," *Journal of Materials Processing Technology*, vol. 63, no. 1–3, pp. 458–462, 1997.
- [8] G. Ghosh, P. Mandal, and S. C. Mondal, "Modeling and optimization of surface roughness in keyway milling using ANN, genetic algorithm, and particle swarm optimization," *International Journal of Advanced Manufacturing Technology*, vol. 100, no. 5, pp. 1223–1242, 2019.
- [9] A. Kaveh and S. M. Rad, "Hybrid genetic algorithm and particle swarm optimization for the force method-based simultaneous analysis and design," *Iranian Journal of Science and Technology Transaction B: Engineering*, vol. 34, p. 22, 2010.
- [10] R. J. Bensingh, R. Machavaram, S. R. Boopathy, and C. Jebaraj, "Injection molding process optimization of a bi-aspheric lens using hybrid artificial neural networks (ANNs) and particle swarm optimization (PSO)," *Measurement*, vol. 134, pp. 359–374, 2019.
- [11] G. Anitha, M. Ayyadurai, and G. Ramkumar, "Design of miniaturized single bit MEMS phase shifter using MEMS switches," in *Proceedings of the 2021 5th International Conference on Trends in Electronics and Informatics (ICOEI)*, pp. 235–239, IEEE, Tirunelveli, India, June 2021.
- [12] M. S. Meiabadi, A. Vafaesefat, and F. Sharifi, "Optimization of Plastic Injection Molding Process by Combination of Artificial Neural Network and Genetic Algorithm," *Journal of Optimization in Industrial Engineering*, vol. 6, 2013.
- [13] V. Singh, G. Anitha, and K. Usha Kiran, "Conventional DMTL phase shifter is designed without meta-material and with meta-material," in *Optical and Microwave Technologies*, pp. 21–32, Springer, Berlin, Germany, 2018, Lecture Notes in Electrical Engineering.
- [14] W.-C. Chen and D. Kurniawan, "Process parameters optimization for multiple quality characteristics in plastic injection molding using Taguchi method, BPNN, GA, and hybrid PSO-GA," *International Journal of Precision Engineering and Manufacturing*, vol. 15, no. 8, pp. 1583–1593, 2014.
- [15] G. Ramkumar, R. Thandaiah Prabu, N. Phalguni Singh, and U. Maheswaran, "Experimental analysis of brain tumor detection system using Machine learning approach," *Materials Today: Proceedings*, 2021, In press.
- [16] B. Ozelcik and T. Erzurumlu, "Comparison of the warpage optimization in the plastic injection molding using ANOVA, neural network model and genetic algorithm," *Journal of Materials Processing Technology*, vol. 171, no. 3, pp. 437–445, 2006.
- [17] P. J. Ross, *Taguchi Techniques for Quality Engineering: Loss Function, Orthogonal Experiments, Parameter and Tolerance Design*, MCGRAW-Hill, New York, NY, USA, 1996.
- [18] R. Sreenivasulu, "Optimization of surface roughness and delamination damage of GFRP composite material in end milling using Taguchi design method and artificial neural network," *Procedia Engineering*, vol. 64, pp. 785–794, 2013.
- [19] R. Govindaraj and E. Logashanmugam, "Multimodal verge for scale and pose variant real time face tracking and recognition," *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 13, no. 2, p. 665, 2019.