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# A Brief Literature Review on Optimization of Plastic Injection Moulding Process Parameters for Various Plastic Materials by using Taguchi's Technique

Prashant K Mulge
Assistant Professor
Faculty of Engg. & Tech.(Co.Ed.)
Department of Mechanical Engineering
Sharnbasva University Kalaburagi
Karnataka-India

Dr. Shashidhar S Kalashetty
Professor & HOD
Head of Research Centre
Department of Industrial & Production Engg.
PDA College of Engineering Kalaburagi
Karnataka-India

***Abstract*: —Plastic molding processes are used to produce plastic parts and components, which finds applications in many industrial as well as household consumer products. Plastic injection molding is really a challenging process for designers, researchers and manufacturers to produce the components or products at low cost, meeting all the necessary requirements from the customers. In today's plastic age, injection molding industry is facing a huge competition. Using a conventional trial-and-error approach for finding out the desired processing conditions for molding is not good enough to sustain in the global market. Many product designing, mold designing aspects as well as large number of process parameters need to be optimized in order to meet customer requirements and expectations regarding quantity, quality and performance of the product at a competitive price. The objective of this paper is to provide an insight of literatures about recent research in optimization aspects for determining optimum process parameters of plastic injection molding process by using Taguchi's technique.**

***Keyword: Plastic injection moulding, PIM parameters, Taguchi Technique, optimization methods.***

## 1. INTRODUCTION.

Plastic Injection Molding process has been a very challenging process for many manufacturers and researchers to make a component meeting all the expectations of the customer at low cost and in minimum time. In today's rapidly rising market demand, injection molding holds the responsibility of a mass production of the plastic components. Hence every manufacturer has to take care that the cycle time of the molding process is optimized properly to meet the market demand.[1]

Optimizing process parameter problems is routinely performed in the manufacturing industry. Final optimal process parameter setting is recognized as one of the most important steps in injection molding for improving the quality of molded products. Previously, engineers used trial-and-error processes which depend on the engineers' experience and intuition to determine initial process parameter settings. [2]

## 2. PLASTIC INJECTION MOULDING PROCESS.

This is the most common method of producing parts made of plastic. The process includes the injection or forcing of heated molten
plastic into a mold which is in the form of the part to be made. Upon cooling and solidification, the part is ejected and the process continues. The injection molding process is capable of producing an infinite variety of part designs containing an equally infinite variety of details such as threads, springs, and hinges, and all in a single molding operation. A plastic is defined as any natural or synthetic polymer that has a high molecular weight. There are two types of plastics, thermoplastics and thermoset. Thermosets will undergo a chemical reaction when heated and once formed cannot be resoftened. The thermoplastics, once cooled, can be ground up and reheated repeatedly. Thus, the thermoplastics are used primarily in injection molding.[7]
There are four major elements that influence the process.
They are:

- The molder
- The material
- The injection machine
- The mold

Of these four, the injection machine and the mold are the most varied and mechanically diverse. Most injection machines have three platens. Newer models use just two platens and may be electrically operated as opposed to the traditional hydraulic models. They can range in size from table top models to some the size of a small house. Most function horizontally, but there are vertical models in use. All injection machines are built around an injection system and a clamping system. Injection molding is a process of forming an article by forcing molten plastic material under pressure into a mould where it is cooled, solidified and subsequently released by opening the two halves of the mould. Injection molding is used for the formation of intricate plastic parts with excellent dimensional accuracy. A large number of items associated with our daily life are produced by way of injection molding. Typical product categories include house wares, toys, automotive parts, furniture, rigid packaging items, appliances and medical disposable syringes.[12]

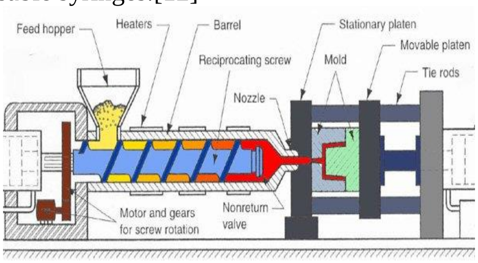


Figure:1 Plastic Injection Moulding Machine

### *2.1 Advantages of Injection Molding*

- ➢ Accuracy in weight of articles
- ➢ Choice of desired surface finish and colours
- ➢ Choice of ultimate strength of articles
- ➢ Faster production and lower rejection rates
- ➢ Faster start-up and shut down procedures
- ➢ Minimum wastage
- ➢ Stability of processing parameters
- ➢ Versatility in processing different raw materials

## 3. PLASTIC INJECTION MULDING PROCESS PARAMETERS

There are a number of machine settings that allows the control of all steps of slurry or melt preparation, injection in to a mold cavity and subsequent solidification. Some important parameters of them are like Injection pressure, Injection speed, mold temperature, Processing Temperature; hold pressure, Back pressure, Hydraulic oil temperature, Cooling time, Suck back pressure etc.

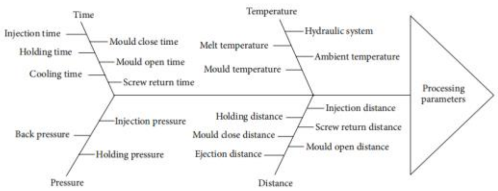


Figure 2: Ishikawa diagram of processing parameters in injection moulding.[17]

## 4. TAGUCHI'S OPTIMIZATION TECHNIQUE

Taguchi's concept is based on the effective application of engineering approach rather than advanced statistical analysis. It focused on both upstream and shop-floor quality engineering concept. Upstream methods effectively reduce the cost and variability by use of small-scale experiments, and used robust designs for large-scale production and market aspect. Shop-floor techniques facilitate economical, real time methods for monitoring and maintaining quality aspects in production. The farther upstream a quality method is applied, the greater leverages it produces on the improvement, and the more it reduces the cost and time. The cost of quality should be measured as a function of deviation from the standard and the losses should be measured system-wide. Taguchi proposes an off-line strategy for quality improvement as an alternative to an attempt to inspect quality into a product on the production line. He observes that poor quality cannot be improved by the process of inspection, screening and salvaging. No amount of inspection can put quality back into the product. Taguchi recommends a three-stage process: system design, parameter design and tolerance design. His approach gives a new experimental strategy in which a new developed form of design of experiment is used. In other words, the Taguchi approach is a form of DOE with some new and special application approach. This technique is helpful to study effect of various process parameters (variables) on the desired quality and productivity in a most economical manner. By analyzing the effect of various process parameters on the results, the best factor combination taken [10]. Taguchi designs of experiments using specially designed tables known as "orthogonal array". With the help of these experiments table the design of experiments become the use of these tables makes the design of experiments very easy and consistent [11] and it requires only few number of experimental trials to study the entire system. In this manner the whole experimental work can be made economical. The experimental outcomes are then transformed into a S/N ratio. Taguchi suggest the use of the S/N ratio to investigate the quality characteristics deviating from the standard values. Usually, there are three type of classification of the quality characteristic in the study of the S/N ratio, i.e. the-lower-the better, thehigher-the-better, and the nominal-the-better. The S/N ratio for each category of process parameters is computed based on the S/N analysis. Regardless of the category of the quality characteristic, a greater S/N ratio corresponds to better quality characteristics. Therefore, the optimum level of the process parameters is the level with the greatest S/N ratio, so in this manner the optimal combination of the process parameters can be predicted.

### *4.1 Types of S/N ratio*

**Larger- the- better:** $S/N = -10 \log 10(1/n\ \Sigma\ 1/yi^2)$
Where, i=1 to n, n = no. of replications applied to the problems where maximization of quality characteristics of interest is needed.
**Smaller- the- better:** $S/N = -10 \log 10(1/n\ \Sigma\ yi^2)$
It is used where minimization of the characteristics is intended
**Nominal-the-best:** $S/N = -10 \log 10\ [\mu^2 / \sigma^2]$
Taguchi Parameter Design Fallows chronological sequence as

- ➢ Selection Of Quality Characteristics
- ➢ Selection of Control Factors and Noise Factors
- ➢ Selection of Orthogonal Arrays
- ➢ Analysis of Results
- ➢ Confirmation of results

## 5. LITERATURE REVIEW

A lot of research is being carried out to understand and identify the effect of plastic injection moulding process parameters on the quality of the plastic product. Till today many optimization techniques were used to control the plastic injection process parameters.

Harshal P.Kale et al.[1], studied the effect of melt temperature, injection pressure, packing pressure and cooling time on HDPE material to reduce the shrinkage. In this paper optimal injection moulding condition for minimum shrinkage were determined by the DOE technique of Taguchi methods. The determination of optimal process parameters were based on S/N ratios.

Junhui Liu et al.[2], in this paper the authors studied on set of procedures for the optimization of injection moulding process parameters(IMPP), in this study the optical performance and the surface waviness were the two output characteristics of the plastic material. First, the orthogonal experiment was carried out with the Taguchi method, and the results were analyzed by ANOVA to screen out the IMPP having a significant effect on the objectives. Then, the $3^4$ full-factor experiment was conducted on the key IMPP, and the experimental results were used as the training and testing samples.

D.Venkatesa Prabu et al.[3], in this paper the authors studied four process parameters namely, holding pressure, barrel temperature ,mould temperature, and injection speed were considered. The authors main focus of this paper was laid on jewellery making like Gold, Silver, Platinum, copper in injection moulding.

Sokkalingam Rajalingam et al.[4], in this paper the authors made an attempt to decrease the shrinkage of the cell phone cover material which was made up of poly carbonate (PC). The PIM process parameters which were considered by the authors in this study were namely mold temperature, injection pressure and screw rotation speed. They used surface response methodology to optimise the parameters to control the size and shape of the cell phone cover.

Aditya M. Darekar et al.[6], in this paper the authors studied about an insight of literatures about recent research in optimization aspects for determining optimum process parameters of plastic injection molding. After the reviewing of various literature the authors said that parametric study of the injection molding process parameters using Finite Element Simulations and their interactions for optimizing the process using full factorial design of experiments so that one can get an exact solution.

Harshal P. Kale et al.[7], in this paper the authors made a review on optimal injection molding condition for minimum shrinkage were determined by the DOE technique of Taguchi methods. The various observation has been taken for material namely HDPE. The determination of optimal process parameters were based on S/N ratios. The authors after reviewing said that Taguchi approach has potential for savings in experimental time and cost on product or process development and quality improvement. The authors also said that Taguchi and ANOVA methods were used to investigate the effects of melt temperature, injection pressure, packing pressure, packing time and cooling time on the shrinkage of the HDPE material.

Anand Dwiwedi et al.[8], in this research article the authors made an attempt to investigate the effect of PIM process parameters namely Injection Pressure, Injection speed, processing temperature and cooling time on tensile strength of poly propylene(PP) material by optimizing the parameters with the help of Taguchi $L_9$ orthogonal array. From the results it was concluded that the processing temperature plays an important role to increase the tensile strength of PP material.

Wen-Chin Chen et al.[9], in this paper the authors proposed a systematic optimization model of process parameters in plastic injection molding (PIM). Here authors made an attempt to find out the best optimization technique to optimize the process parameters namely melt temperature, injection velocity, packing pressure, packing time, and cooling time. The output characteristics effect they had studied Warpage and shrinkage. The authors concluded that the hybrid optimization technique was the best for optimization of PIM process parameters.

Satadru Kashyap et al.[10], in this research article the authors studied the various optimization techniques for optimization of plastic injection moulding process parameters. The different optimization techniques which were studied by the authors are Taguchi method for design of experiment(DOE), Artificial neural network (ANN), Evolutionary algorithm (EA), Genetic algorithm (GA) and hybrid techniques. From their review the authors had concluded that a complete intelligent technique operable without human interference was yet to be developed.

Shih-Chih Nian et al.[11], in this paper the authors studied about the reduction of Warpage .The local mold temperature settings for a cooling system that can prevent severe warpage in an asymmetric plastic cover for handheld communication devices. Through simulation and experiments conducted in this study, the feasibility of using an effective local mold temperature setting in a cooling system to reduce part Warpage was verified.

Xuan-Phuong et al.[12], this paper reviews the state-of-the-art of injection molding process parameters optimization. The existence of many methods and techniques applied to molding parameters optimization shows that there is no perfect method to solve all optimization problems. However, usable frameworks and appropriate guidelines can be generalized to facilitate the optimization process in injection molding design. The authors introduced two robust general optimization frameworks for optimizing molding parameters including direct numerical optimization and meta model based optimization. The proposed frameworks were systematic, general, but very flexible.

Y. P. Tidke et al.[13], in this article the authors reviewed the research of the practical use of Taguchi method in the optimization of processing parameters for injection moulding. After reviewing the various published articles on optimization of plastic injection moulding process parameters for plastic material, the author concluded that the shrinkage of the plastic material can be minimized by optimizing the process parameters like melting temperature, packing pressure and packing time.

Yi-qi Wang et al.[14], in this research article the authors investigated the effect of plastic injection moulding process parameters (number of gates, gate size, molding temperature, resin temperature, switch over by volume filled, switch over injection pressure and curing time) on compression strength of Phenolic molding compound material. The authors concluded that the optimized molding temperature increases the compression strength of the material.

Sanjay N. Lahoti et al.[15], in this research article the authors studied injection molding process parameters for three different thermoplastic materials with at least two varieties in each. And they developed a method to produce defects free parts by controlling the plastic injection moulding process parameters like melt temperature, injection pressure, injection velocity, injection time, packing pressure, packing time, cooling temperature, cooling time. The authors used mould flow software for the research.

Sajjan Kumar Lal et al.[16], in this research paper the authors investigated the effects of melting temperature, injection pressure, refilling pressure and cooling time on the shrinkage of LDPE. The main objective of this article was to reduce the shrinkage of the plastic material by optimizing the plastic injection process parameters. In this study, optimal injection moulding conditions for minimum shrinkage during moulding are found by DOE technique (Taguchi method). The authors concluded that the cooling time was the most effective factor for LDPE followed by refilling pressure and injection pressure was found to be the least effective factor.

Ng Chin Fei et al.[17], in this paper the author aims to review the research of the practical use of Taguchi method in the optimization of processing parameters for injection moulding. Taguchi method has been employed with great success in experimental designs for problems with multiple parameters due to its practicality and robustness. However, the authors were realized that there is no single technique that appears to be superior in solving different kinds of problem.

Dragan Kusic et al.[18], the aim of the authors of this paper was to investigate the influence of six injection moulding process parameters on the post-moulding shrinkage and warping of parts made from polypropylene filled with calcium carbonate, as used in large quantities throughout the automotive industry. Here the authors scanned each test specimen using an optical 3D scanner for accuracy. From the results it was revealed that the packing pressure had the most influential parameter on shrinkage.

Mohd. Muktar Alam et al.[19], in this paper the authors studied the effect of plastic injection process parameters Melt temperature ,Injection pressure ,packing pressure and Packing time on reducing the shrinkage for polypropylene material by using Taguchi method. From the results it was revealed that packing pressure found most influential parameter for reducing the shrinkage of the material.

Rishi Pareek et al.[20], in this paper the authors deals with the effects of parameters selection on injection moulding using Taguchi and ANOVA. The objective of this paper was to define suitable parameters in producing plastic product in term of strength. This paper describes the effect of temperature, pressure and cooling time. Plastic material polycarbonate was studied in this paper which commonly used in industries. injection moulding machine with different melt temperature, injection pressure, and cooling time.. By using Taguchi and ANOVA an optimum value or the best value of melting temperature, injection pressure and cooling time is obtained.

Wu-Lin Chen et al.[21], in this study the authors considered three quality indices in the plastic injection molding: war page, shrinkage, and volumetric shrinkage at ejection. A digital camera thin cover was taken as an investigation example to show the method of finding the efficient frontier. Solidworks and Moldflow were utilized to create the part's geometry and to simulate the injection molding process, respectively. Nine process parameters were considered in this research: injection time, injection pressure, packing time, packing pressure, cooling time, cooling temperature, mold open time, melt temperature, and mold temperature. Taguchi's orthogonal array $L_{27}$ was applied to run the experiments, and analysis of variance was then used to find the significant process factors.

M. V. Kavade et al.[22], in this research article the authors investigated the effects of plastic injection moulding parameters namely Barrel temperature, Injection Pressure ,injection speed, coolant flow rate, holding pressure, holding time and cooling time on the polypropylene material to control the weight of the component . The main objective if the author was to reduce the total weight of the component by varying the plastic injection moulding process parameters. The reduction in weight of the component will reduce the consumption of raw material that will increase the profit. From the results the authors revealed that the barrel temperature plays a vital role in reduction of the weight of the polypropylene component.

Radhwan Hussin et al.[23], in this paper the authors investigated the effects of plastic injection moulding process parameters like cooling temperature, ambient temperature, mould temperature, packing time, melt temperature, packing pressure and runner size on Acrylonitrile Butadiene Styrene(ABS) thermoplastic material to reduce the warpage defect. Here the authors used Moldflow plastic insight (MPI) simulation software and for optimization of process parameters they used Taguchi's method and analysis of variance (ANOVA). From the results the author's revealed that melt temperature of the thermoplastic was most important to control the warpage defect and they also confirmed from their experimental analysis, 12% of warpage was reduced after optimizing the process parameters.

Rashi A.Yadav et al.[24], in this published paper the author's made an attempt to study the various recent optimization techniques for plastic injection moulding process parameter optimization in order to improve the quality of the plastic products and decrease the cost of product. The author's compared so many optimization techniques namely mathematical model, genetic algorithms, finite elemental analysis, linear regression analysis, grey rational analysis, Taguchi method, principle component analysis, artificial neural network etc. From the review it was concluded by the authors that Taguchi optimization technique was the best method for controlling the plastic injection moulding process parameters. The Taguchi method reduces the cost of the product/process

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and it also had the capacity to optimize the uncontrollable factors like environmental variables.

M.G. Rathi et al.[25], in this research paper the authors had studied about the effect of plastic injection moulding process parameters on Chlorinated Poly Vinyl Chloride (CPVC) material to reduce the weight of the CPVC material. In order to optimize the process parameter the authors were used Taguchi's technique. From the experimental results the author's concluded that the mould closing speed had very high effect on weight of the CPVC material and they had also stated that mould pressure and injection pressure had no effect on deciding the weight of the CPVC material.

M. Stanek et al.[26], in this paper the authors studied about the a very new technique Moldflow plastic xpert (MPX). The authors said that the MPX combines process setup, real time optimization and production control according to set process parameters in one system. The MPX system not only optimizes the plastic injection process parameters but also reduces the time and improves the quality of product by removing all the defects.

Alireza Akbarzadeh et al.[27], in this research article the authors made an attempt to investigate the effects of plastic injection moulding process parameters like injection pressure, melting temperature, packing time and packing pressure on two plastic materials namely polystyrene and polypropylene to reduce the shrinkage of these materials. In this experimental work the authors used regression method and analysis of variance (ANOVA) to analysis process parameters and they used Invasive Weed Optimization (IWO) optimization method. Form the ANOVA results the authors revealed that packing pressure was the most effective parameter and injection pressure was the least important to reduce warpage for polypropylene material. Similarly melting temperature was most influential variable while packing pressure and packing time are next important to reduce the warpage for polystyrene material.

Ching-Piao Chen et al.[28], in this research paper the authors compared simulation and the experimental optimization methods to control the warpage of polyamide PA9T material. The authors studied the plastic injection process parameters namely melt temperature, mould temperature, injection speed and packing pressure. From the ANOVA results the authors revealed that melt temperature and packing pressure both were found to be the most suitable significant process parameters for reducing the warpage of polyamide PA9T material.

J.Jin et al.[29], in this research article the authors studied the effects of plastic injection moulding process parameters namely flow rate, mold temperature , packing pressure, melt temperature and packing time on polycarbonate (PC) material to reduce the shrinkage and warpage defects. The authors used analysis of variance (ANOVA) and Taguchi's method to identify the most influential process parameters. From the results the authors had revealed that the optimized process parameters reduced the defects like, warpage and shrinkage.

Yi mei et al.[30], in this research article the authors had studied about the model which determined the complex and nonlinear relationships between the plastic injection moulding process parameters and the defects of plastic injection moulding parts. Here the authors used a genetic algorithm (GA) to determine a set of optimal parameters for support vector machine.

S.H. Tang et al.[31], in this paper the authors made an attempt to investigate the effects of plastic injection moulding process parameters like, packing pressure, packing time, melt temperature and filling time on ABS plastic material to reduce the warpage defect. In this experimental research the authors manufactured a thin plastic plate of dimensions 120mm X 50mm and 1mm thickness. Here the Taguchi's optimization technique was used to analyse the effects of process parameters on quality of the product. From the results the authors had revealed that melt temperature was the most influential factor on warpage of ABS plastic material. And it was also noted that the filling time had only small influenced on warpage defect.

Hasan Oktem et al.[32], in this research article the authors applied the Taguchi's optimization technique to reduce the warpage and shrinkage defect of ABS material by optimizing the plastic injection moulding process parameters like injection time, packing pressure, packing time and cooling time. Analysis of variance (ANOVA) was used to find the optimum process parameters. The results revealed that warpage and shrinkage were reduced by optimizing the process parameters.

B. Berginc et al.[33], in this paper the authors made an attempt to investigate the effects of plastic injection moulding process parameters on warpage and shrinkage of plastic material. Here the Taguchis and analysis of variance (ANOVA) were used to optimize the process parameters. The selected process parameters in this study were material temperature, injection speed, duration of holding pressure, holding pressure, cycle time and mould temperature. From the results the authors had concluded that the mould temperature played a vital role in the variations of results(Warpage & shrinkage) and it was also noted that injection speed and holding pressure do not had such a big influence on the shrinkage.

B. Ozcelik et al.[34], in this paper the authors made an attempt to investigate the effects of plastic injection moulding process parameters on warpage and shrinkage of plastic material. In this experimental work computer aided analysis and engineering software were used to control the process parameters like melt temperature, packing pressure, packing time, cooling time, runner type and gate locations. The most important process parameters influencing warpage were determined using finite elemental software Moldflow.

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## 6. RESULTS AND SUMMARY

From the literature review it is found that many authors studied on optimizing the process parameters for plastic injection molding on various kind of plastic materials by using Taguchi technique and some of them are summarised below.

| Sl No. | Title of the Research paper | Paper published year | Material on which research done | PIM, Process Parameters studied | Outcome from the research paper |
|---|---|---|---|---|---|
| [01] | Optimization of injection moulding process for reducing shrinkage of high density polyethylene (HDPE) material. | 2017 | High density polyethylene (HDPE) 080M60 grade | ❖ Melting temperature (180-200$^0$C)<br>❖ Injection pressure(40-60 MPa)<br>❖ Packing pressure(25-35 MPa)<br>❖ Cooling time (20-30 Seconds | ❖ Shrinkage of the HDPE material decreases with increase in melt temperature.<br>❖ Melt temperature is the most effective parameter for shrinkage. |
| [02] | Multi objective optimization of injection molding process parameters for the precision manufacturing of plastic optical lens. | 2017 | Poly methyl methacrylate acrylic (PMMA) | ❖ Melt temperature (220-230$^0$C)<br>❖ Injection velocity (60-80 mm/sec)<br>❖ Injection pressure(80-100 MPa)<br>❖ VP switchover (5.2-5.4 mm)<br>❖ Packing time (4-8 sec)<br>❖ Packing pressure (90-110 MPa)<br>❖ Mold temperature (60-90$^0$C)<br>❖ Cooling time(15-35 sec) | ❖ With the increase in injection pressure the optical performance of the lens material decreases continuously.<br>❖ With the increase in cooling time, the lens surface waviness is increased substantially at the beginning & decreased slightly subsequently. |
| [03] | Optimization of injection molding process parameters for a plastic cell phone housing Component. | 2016 | Poly carbonate (PC) | ❖ Mold temperature (85-95$^0$C)<br>❖ Injection pressure (2250-2400 kg/cm$^2$)<br>❖ Screw rotation speed (110-140 mm/sec) | ❖ The shrinkage of PC (mobile phone) in length and width is less when all the process parameters are set to medium/centre values. |
| [04] | Practical application of Taguchi method for optimization of process parameters in Injection Molding Machine for PP material. | 2015 | Poly Propylene (PP) | ❖ Injection pressure (120-140MPa)<br>❖ Injection speed (50-90 mm/sec)<br>❖ Processing temperature (180-220$^0$C)<br>❖ Cooling time (10-20 Sec) | ❖ The tensile strength of the polypropylene material is increased by increasing the processing temperature. |
| [05] | Optimization of plastic injection molding process parameters for manufacturing a brake booster valve body. | 2014 | Phenolic molding compound (CY3915 30G) | ❖ Number of gates (2-4)<br>❖ Gate size(19-23 mm)<br>❖ Molding temperature(148-181$^0$C)<br>❖ Resin temperature (86-105$^0$C)<br>❖ Switch over by volume filled (70-81%)<br>❖ Switch over by injection pressure(11-14MPa)<br>❖ Curing time (108-132 Sec) | ❖ Resin temperature has more effect on resin viscosity.<br>❖ Molding temperature has less effect on compression strength and curing percentage. |
| [06] | Optimization of Injection Moulding Process Parameters in the Moulding of Low Density Polyethylene (LDPE). | 2013 | Low density poly ethylene (LDPE) 16MA400 | ❖ Melting temperature (190-210$^0$C)<br>❖ Injection pressure (55-70 MPa)<br>❖ Refilling pressure (75-85 MPa)<br>❖ Cooling time (7-11 Sec) | ❖ The shrinkage of LDPE is decreased by maintaining minimum melting temperature and minimum injection pressure.<br>❖ The shrinkage of LDPE is got increased by increasing the refilling pressure and cooling time. |

| Sl No. | Title of the Research paper | Paper published year | Material on which research done | PIM, Process Parameters studied | Outcome from the research paper |
|---|---|---|---|---|---|
| [07] | The impact of process parameters on test specimen deviations and their correlation with AE signals captured during the injection moulding cycle. | 2013 | Polypropylene (PP) with 40% calcium carbonate | ❖ Melt temperature (230-240$^0$C)<br>❖ Injection speed (40-50 mm/sec)<br>❖ Injection pressure (1000-1200 bar)<br>❖ Packing pressure (300-500 bar)<br>❖ Packing time (3-5 sec)<br>❖ Cooling time (6-10 sec) | ❖ The packing pressure and packing time are the most effective parameters for controlling the shrinkage of PP.<br>❖ The acoustic emission testing is most suitable for analysing the good and bad specimens. |
| [08] | Reducing Shrinkage in Plastic Injection Moulding using Taguchi Method in Tata Magic Head Light. | 2013 | Polypropylene (PP) | ❖ Melt temperature (220-280$^0$C)<br>❖ Injection pressure (55-70 MPa)<br>❖ Packing pressure (35-60 MPa)<br>❖ Packing time (5-10 Sec) | ❖ Packing pressure plays an important role to reduce the shrinkage of Polypropylene (PP) material. |
| [09] | Optimization of Injection Moulding Process using Taguchi and ANOVA. | 2013 | Polycarbonate (PC) | ❖ Melt temperature (260-320$^0$C)<br>❖ Injection pressure (90-150 bar)<br>❖ Cooling time (7.5-30 Sec) | ❖ The melting temperature is the most effective parameter to increase the tensile strength of polycarbonate material. |
| [10] | Parameter Optimization of Injection Molding of Polypropylene by using Taguchi Methodology. | 2012 | Polypropylene (PP) | ❖ Barrel temperature (215-235$^0$C)<br>❖ Injection pressure (30-45 MPa)<br>❖ Injection speed (40-50 mm/Sec)<br>❖ Coolant flow rate (4-11 mm/sec)<br>❖ Holding pressure ( 35-45 MPa)<br>❖ Holding time (1.5-2 sec)<br>❖ Cooling time (5.5-6 sec) | ❖ The barrel temperature and injection pressure are the two main process parameters to decrease the weight of the polypropylene component.<br>❖ The decrease in the weight of the component reduces the consumption of raw material. |
| [11] | An Optimization of Plastic Injection Molding Parameters Using Taguchi Optimization Method. | 2012 | Acrylonitrile Butadiene Styrene (ABS) | ❖ Mold temperature (60-100$^0$C)<br>❖ Melt temperature (240-280$^0$C)<br>❖ Packing time (8-12 Sec)<br>❖ Packing pressure (140-160 MPa)<br>❖ Cooling time (17-25 Sec)<br>❖ Cooling temperature (22-30$^0$C)<br>❖ Ambient temperature (20-35$^0$C)<br>❖ Runner size (5-8 mm) | ❖ The melt temperature is the most important factor to control the Warpage defect of ABS.<br>❖ 12% decreases in Warpage defect after applying the optimised parameters to ABS material. |
| [12] | Analysis of injection process parameters | 2012 | Chlorinated poly vinyl chloride (CPVC) | ❖ Injection pressure (85-125 bar)<br>❖ Mold closing speed (90-200 mm/sec)<br>❖ Mold pressure (80-90 bar)<br>❖ Back pressure (15-40 bar) | ❖ The mold closing speed is the most important factor to reduce the weight of the CPVC material. |
| [13] | Optimization of plastic injection molding process parameters for thin-wall plastics injection molding | 2009 | Acrylonitrile Butadiene Styrene (ABS) | ❖ Mold temperature (60-80$^0$C)<br>❖ Melt temperature (250-300$^0$C)<br>❖ Flow rate (12-16 $cm^3$/Sec)<br>❖ Packing pressure (70-90 MPa)<br>❖ Packing time (4-8 Sec) | ❖ Optimization parameters gives less Warpage and shrinkage for ABS material. |

## 7. CONCLUSION

A brief review of literature on optimization of plastic injection moulding process parameters has revealed that there are so many optimization tools and techniques are available, a lot of work had done by so many authors in this area. So special attention are required in this area. Because based on this study we know that due to processing parameters many defects occur. So for the production of product control of processing parameters is required. Taguchi methods are robust design techniques widely used in industries for making the product/process insensitive to any uncontrollable factors such as environmental variables. Taguchi approach has potential for savings in experimental time and cost on product or process development and quality improvement.

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ABOUT THE AUTHORS

**PRASHANT K MULGE**

working as Assistant professor in Faculty of Engineering & Technology (Co.Ed.), Department of Mechanical Engineering, Sharnbasva University, Kalaburagi, Karnataka, India. He completed M.Tech. In Production Engineering from Visvesvaraya Technological University. And currently doing Ph.D. at Visvesvaraya Technological University. His area of research includes Optimization techniques, Plastics, Casting, effect of process parameter on product etc.

**Dr. SHASHIDHAR S KALASHETTY** Working as

Professor & Head of the research centre, Department of Industrial & production Engineering, PDA College of Engineering, Kalabuargi, Karnataka-India. He received Ph.D. from Visvesvaraya Technological University, received his M.Tech. degree from IIT, Kharagpur. His area of research includes Product design, Ergonomics, design & development of agriculture equipment's. In his supervision currently 8 students are doing Ph.D.