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"A REVIEW ON OPTIMIZATION OF INJECTION MOULDING PROCESS WITH MELTING TEMPERATURE PARAMETERS"

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ABSTRACT

This review paper identified superior optimization methods for shrinkage effects of various molding process parameters. The form configuration can affix the shape creating plan, in this manner abbreviate the pattern of item. advancement, and work on the nature of items and the serious capacity of big business. One of the most important and common methods of making plastic is injection molding. The optimal process conditions for the injection molding of a specific part can be determined by combining modeling tools and optimization algorithms. It is no longer sufficient to employ the trail-and-error approach parameters for injection molding. Therefore, the focus of this work has been on locating processing parameter optimizations for robust parameter design. The artificial neural network method, which yields useful results, was used to solve the problem in this study.

Key Words: *Injection moulding, optimization, Process parameter, ANN tool, Shrinkage*.

I. INTRODUCTION

Injection Molding is being used. John Wesley Hyatt and his brother Isaiah, both American inventors, came up with the idea for the machine in 1872 and patented it the following year. The machine was simple in comparison to the sophisticated equipment that is used nowadays. To inject plastic into a mould via a heated cylinder, it operated much like a big hypodermic needle, with a plunger being used to push the material forward. Plastic goods have not been used in the production of items needed in day-to-day life since 1978, despite the fact that the manufacturing technique of injection moulding is no longer in demand. Nevertheless, as time goes on, items made of plastic materials are gradually replacing those made of metals and non-metallic materials. The rise in industrialization and general societal progress over the last three decades is largely responsible for the meteoric rise in demand for this particular piece of equipment. Toys, home goods, automobile components, and consumer electronics are all examples of things that are made using the injection moulding method since it is so prevalent in modern life. An injection moulding machine may also make containers buckets, plastic toys, plastic toys, goods for medical equipment, tiny plastic fasteners, and bottles, among other things.

OVERVIEW

When producing high-quality plastic goods, the producer will often take into consideration many components of the manufacturing process. The products have to be able to fulfillment the requirements laid out by the customers, the amount of energy used and the cost of production have to be kept to a minimum, the mechanical properties of the plastic product, which are gained by the product during the processing and are dependent on the parameters, can be regulated to ensure that the product is free of flaws.

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II. LITERATURE REVIEW

Both the injection moulding process's settings and its environment may have an impact on the final product's quality. Several factors, including processing temperature, processing length, pressure, and environmental conditions, might alter conditions during the injection processing phase. All of these parameters have the potential to influence the injection moulding process in some way, including the dimensional errors, mechanical quality, and manufacturing cycle times. There has been a major transition away from the traditional injection moulding technique and toward the gas injection moulding process due to advancements in the moulding of larger, more complex parts.

This shift has occurred throughout the last several decades *(Guo et.al.[2014] [4])*. Because frequent testing and inspections ensure that the machinery is in good working order. There still has to be a floor under the product's quality, however. When there are numerous unseen factors, such as variation in physical properties (for example, when regrind resins are used), changes in the ambient environment (for example, humidity or temperature in the shop), and characteristics of the machine, the procedure conditions are re-read to lower the quality of the part within the tolerance limit (especially when using hydraulic power). Many experts have spent the better part of the past two decades studying effective process control systems. These researchers have used automated and adaptive quality control in addition to specialised control methods to address the aforementioned challenges. The machine was simple in comparison to the sophisticated equipment that is used nowadays. To inject plastic into a mould via a heated cylinder, it operated much like a big hypodermic needle, with a plunger being used to push the material forward. Plastic goods have not been used in the production of items needed in day-to-day life since 1978, despite the fact that the manufacturing technique of injection moulding is no longer in demand. Nevertheless, as time goes on, items made of plastic materials are gradually replacing those made of metals and non-metallic materials. The rise in industrialization and general societal progress over the last three decades is largely responsible for the meteoric rise in demand for this particular piece of equipment. Toys, home goods, automobile components, and consumer electronics are all examples of things that are made using the injection moulding method since it is so prevalent in modern life. It is difficult to develop a practical method of control without first gaining a thorough understanding of the relationships between all of these factors (*Chen and Tung [2005]) [5].*

The specific effort required to locate the optimal solution is proportional to the impact that the parameters have on the answer. The injection pressure must be raised to account for the greater temperature of the molten material if it is too hot. The composition contains a biodegradable component, yet the melting point of that chemical is rather high. There may be a fast shot and a lot of flash within the material if the injection pressure can be maintained exceedingly low (Mok et. al.[1999]) [6]. Thus, to reduce defects as much as possible, it is preferable for the interaction between melting temperature and injection pressure to be larger than that between holding pressure and injection pressure (Kamaruddin et. al.[2010]) [7] .

Key factors include barrel melting temperature, mould temperature, and mould cooling temperature, as well as injection pressure, packing pressure, cooling time, packing time, injection time, and injection environment. The air current, humidity, and temperature are all examples of parameters that play important roles in this scenario (Parey, A. et al. [2007]) [8].

The qualities of the procedure are what ultimately decide the product's final form. There have been several studies using a wide variety of adaption strategies based on the circumstances of the components impacting the injection moulding process (Pandey and Panda [2014] [9]. Solutions to this kind of issue may be found in a number of different places. These techniques use the process's characteristics to determine the best areas to concentrate product development efforts. Optimization strategies including the response surface model, bringing model, artificial neural network, and genetic algorithm have been provided, along with hybrid strategies that take into account their characteristics, advantages, downsides, and scope, as well as the worries of previous researchers (Singh, S. et al. [2013]) [10]. There are three primary types of optimization strategies: those that do not rely on gradients, those that do rely on them, and hybrid strategies that include aspects of both. It is possible to classify various numerical optimization techniques into subgroups according on the degree to which they move the design goal forward with each iteration. In brief, it consists of the following:

The objective function f (x) used in the non-gradient-based technique is independent of derivatives of x, which sets it apart from other optimization strategies (x). Optimization strategies that don't use gradients include adaptive simulated annealing, Hooke-Jeeves direct search, and the genetic algorithm. However, these optimization strategies need a large number of function evaluations to get a globally optimal answer. For instance, the genetic algorithm is a well-known substitute for gradient-based optimization. This method is an evolutionary descendant of stochastic search and optimization algorithms. References are made to the works of *Saurabh Kumar Gupta et al* [11]. The gradient of the function at any given time is used to generate search vectors in a gradient-based method. There is a great deal of variability among gradient-based optimization techniques. Examples of well-known optimization methods include Davidson-Fletcher-Powell, mix integer optimization, sequential linear programming, sequential quadratic programming, and generalised reduced gradient. When there are fewer variables, gradient-based methods tend to converge quickly; but, as the number of variables increases, it may be necessary to run the algorithms for a longer length of time. *Srinivas, Vijayaraghavan*, and collaborators provide extensive discussion on this topic (2013) [12]. When attempting to solve very nonlinear optimization problems, gradient-based approaches may run into local extrema. When compared to employing just one optimization strategy, the efficiency loss that results from adopting a hybrid optimization technique that integrates both gradient-based and gradient-based methods is less severe. On the other hand, optimization strategies based on simulation may be split into two distinct groups of strategies:

1. Techniques for direct optimization.
2. Methods for optimization that are based on metamodels

The relationship between the variables used in the input and those used in the output cannot be defined using direct optimization techniques. Techniques such as these include Hybridization-Based Optimization Techniques, Gradient-Based Optimization Techniques, and Non-Gradient-Based Optimization Techniques. Metamodel and hybrid model based optimization have the ability to locate optimum space by picking an appropriate model that creates the relationship between input and output variables *(Dang, X. P. [2014])* [13]. The injection moulding process has to have both an online and an offline quality control checked out. The process may be regulated by the control of process parameters using online artificial intelligence optimization techniques and offline methods for cost minimization. The machine was simple in comparison to the sophisticated equipment that is used nowadays. To inject plastic into a mould via a heated cylinder, it operated much like a big hypodermic needle, with a plunger being used to push the material forward. Plastic goods have not been used in the production of items needed in day-to-day life since 1978, despite the fact that the manufacturing technique of injection moulding is no longer in demand. Nevertheless, as time goes on, items made of plastic materials are gradually replacing those made of metals and non-metallic materials. The rise in industrialization and general societal progress over the last three decades is largely responsible for the meteoric rise in demand for this particular piece of equipment. Toys, home goods, automobile components, and consumer electronics are all examples of things that are made using the injection moulding method since it is so prevalent in modern life. As a result, the goal is to enhance both the production process and the overall quality of the product. In order to do this, a number of researchers investigate different techniques of adaptation by taking into account the reaction as a dimensional defect, mechanical qualities, and cycle periods of the process of building by injection moulding. In this part of the report, the researcher's work has been categorised according to the approaches that were used and the responses that were obtained throughout the research process.

Study based on Taguchi's Method

Ramesh et al. [2015] [14] used Taguchi's approach to analyse the effects of mould temperature, melt temperature, nozzle temperature, and injection pressure on sink marks and weld lines in a vehicle headlight. The goal was to learn how changing the parameters of the procedure impacted the final result. The study's results suggest that the nozzle's temperature may be adjusted to regulate the brightness of the headlight; this temperature should be much lower than the melting point to prevent sink marks and maximise the integrity of the weld lines. Using Taguchi's experimental method and a variety of factors—melt temperature, mould temperature, packing pressure, packing time, rib to wall ratio, rib to gate system, and injection time—*Mathivanan et al.* [2010] [15] investigate the effect of sink markings on depth. The depth of your sink marks will much improve if you reduce the distance between the rib and the feed point. *Erzurumlu and Ozcelik* [2006] [16] used Taguchi's method to explore the Warpage and sink marks responses as a function of rib cross-section, rib layout angle, melt temperature, mould temperature, and packing pressure. They took into account the consequences of rib arrangement angle, as well. This study compares and contrasts three kinds of plastic—polycarbonate/acrylonitrile butadiene styrene (ABS), polyoxymethylene (POM), and nylon-66—with respect to warpage and sink mark depth. The results indicate that Polycarbonate/Acrylonitrile has a higher level of warpage than

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previously thought. Butadiene Sink index and the amounts of Styrene and Nylon-66 are determined to be small. *Scientists Ozcelik et al. [2010]* [17] tested the tensile and impact strength of the plastic substance acrylonitrile-butadiene-styrene. melt temperature, injection pressure, packing pressure, and packing duration were all considered by the study's authors. The tensile strength of the material was found to increase when the packing pressure was increased throughout the experiment. In fact, they discovered this as one of their discoveries. By analysing the data from the experiment, they found that raising the packing pressure improved the material's tensile strength.

Lens optical quality was studied by *Tsai et al.* [2009] [18] who looked at the impacts of melt temperature, mould temperature, injection pressure, and packing pressure. They gave special care to issues of transparency, waveiness, and gloss. Findings indicated that the injection pressure had an effect on the responses. Warpage dimensional defect as a response of plastic products is analysed by *Galantucci and Spina* [2003] [19] using Taguchi's technique. The machine was simple in comparison to the sophisticated equipment that is used nowadays. To inject plastic into a mould via a heated cylinder, it operated much like a big hypodermic needle, with a plunger being used to push the material forward. Plastic goods have not been used in the production of items needed in day-to-day life since 1978, despite the fact that the manufacturing technique of injection moulding is no longer in demand. Nevertheless, as time goes on, items made of plastic materials are gradually replacing those made of metals and non-metallic materials. The rise in industrialization and general societal progress over the last three decades is largely responsible for the meteoric rise in demand for this particular piece of equipment. Toys, home goods, automobile components, and consumer electronics are all examples of things that are made using the injection moulding method since it is so prevalent in modern life. The melt temperature, the packing pressure, and the injection duration all play a role in helping them achieve their goals. They conclude this because their study indicates that plastics with greater melt temperatures have less warping. Melt temperature, mould temperature, and packing time were all considered by *Karasu et al.* [2014] [20] in their investigation of warpage as a potential response. Research shows that Taguchi's technique is preferable to others when considering the time and resources used in manufacturing a product. Taking a leaf out of Taguchi's playbook, *Song et al.* [2007] [21][conduct an experimental investigation of warpage and filling condition in relation to the product's manufacturing process. The process parameters Metering size, Part thickness, melt temperature, injection pressure, and injection velocity help them achieve this. After doing some investigating, they determined that thickness is the single most crucial aspect to think about when moulding plastic components with very thin walls. Using the Taguchi method, *Ghazali et al.* [2011] [22]assessed warpage as a response to the Nylon 66 plastic material manufacturing process manufacture. Independent variables were melt temperature, packing pressure, packing time, and filling time. When melting temperature and packing time are both increased, the quantity of warpage in nylon 66 plastic items is found to decrease. *Liu and Chen* [2004] [23] performed an experiment to analyse the warpage response of Glass-fiber filled polypropylene composites using Taguchi's approach. Some of the variables used in the manufacturing process were the duration of the water injection delay, the water temperature, and the water pressure. In addition, they used the process parameters of melt temperature, mould temperature, and holding duration. Increases in melting temperature of polypropylene composites were shown to reduce warpage. *Ahmad et al.* [2009] [24] used Taguchi's method to assess warpage as the response of an acrylonitrile butadiene styrene plastic product, factoring in melt temperature, mould temperature, packing pressure, and packing time. Their investigation revealed that the two most important variables in regulating warpage in ABS products were melt temperature and mould temperature (ABS).

Research that was conducted using the Response Surface Method

Using the rotatable central composite design response surface approach, *Hazwan et al.* [2017] [25] investigate the Warpage as the response by taking into account melt temperature, packing pressure, cooling time, and coolant temperature as process factors. According to the findings of their investigation, the temperature at which the material is cooled is the factor that has the greatest impact on the dimensional defect warpage. Researchers *Villarreal-Marroquin et al.* [2011] [26] investigated the effects of melt temperature, packing pressure, Center composite design, and Latin Hypercube design of response surface approach on shrinkage and cycle time as responses. According to the findings of their investigation, melt temperature is a major factor in both cycle duration and shrinkage.

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Research using a number of distinct hybridization techniques

The combined reaction of warpage and clamp force is investigated by *Yin et al.* [2011] [27] . The melt temperature, mould temperature, packing pressure, packing duration, and cooling time are all process characteristics that are taken into consideration. The outcomes are then examined with the use of Backpropagation and a genetic algorithm. Their research showed that when packing pressure was raised, warpage decreased and a higher clamping force was needed to keep the material in the mould. Melt temperature, packing pressure, packing duration, and cooling time are all used by Mehat et al. [2012] [28] to calculate an approximation of the shrinkage defect. Taguchi's technique, in conjunction with GRA, is used to achieve this. It was determined that the melt temperature was the most useful processing parameter. Using injection velocity, injection time, and packing pressure as process parameters, *Chen et al.* [2008] [29] polled the same question in terms of product weight. Their investigation led them to conclude that increased pressure during packaging has a significant role in driving product weight up. *Xu et al.* [2015] [30] use particle swarm optimization and artificial neural networks to study the effects of warpage on polycarbonate plastic. They take into account the temperatures of the mould and the melt, as well as the injection velocity. According to the findings of the research, a significant amount of the Warpage may be attributed to the melting temperature. *Gao and Wang* [2009] [31] use the Kriging surrogate model to investigate study Warpage as a response. They use variables such as melt temperature, mould temperature, injection time, packing time, and packing pressure. According to the findings of the research, one of the contributing factors to the warping of plastic goods is the temperature at which the melt occurs. Taguchi's technique, along with desirability function, is used by *Chen et al.* [2009] [32] to assess warpage as a response. They use melt temperature, injection pressure, and packing pressure as process parameters. Both the models and the tests discovered the melt temperature and the filling/packing pressure, with the most important parameters being found. The study statement, problem statement, and aim have all been determined in order to address this gap in knowledge that has been found. According to the assessment of the relevant literature, only a small number of people have worked on polypropylene plastic materials using advanced optimization hybridization approaches.

III. PROBLEM STATEMENT

- To investigate the influence that certain process factors, including as melt temperature, injection pressure, packing pressure, packing time, and cooling time, have on the results of the experiment, particularly process cycle time, tensile strength of components, and dimensional defect warpage.
- The combining of a number of distinct optimization methodologies, such as the Utility idea and the Desirability concept, with the Taguchi method, which encourages the optimum combination with the least amount of error.
- What kinds of opportunities exist for the hybridization of desirability functions in the injection moulding of polypropylene plastic components?
- How can the polypropylene components produced via the injection moulding technique help to the best hybridization components.

IV. CONCLUSION

The following are some of the most important characteristics of an item that has been the subject of this investigation:

- An investigation of the operating ranges and levels of process parameters for making polypropylene components using the injection moulding technique.
- Conduct research on the influence that certain process parameters, including as melt temperature, injection pressure, packing pressure, packing time, and cooling time, have on the length of the process cycle, the tensile strength of the components, and the dimensional defect warpage.
- Combining Taguchi's Design of experiment with the want function and the Utility idea allows for the multi-response optimization of the process parameters of injection moulding polypropylene components.

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- When Taguchi's approach is combined with more modern techniques, integration of weights is figured out with the use of principal component analysis and grey entropy measuring techniques.

- To investigate and analyze, in terms of their respective error percentages, the many possible combinations of hybridization techniques.

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