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DETERMINATION OF PROCESS PARAMETER FOR INJECTION MOLDING: A REVIEW

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Abstract

One of the most suitable methods for mass production of complicated shapes is injection molding due to its superior production speed and quality. Plastic injection is the process of forming products from plastic materials with variations in shape and size. Controlling the quality of plastic products is an important aspect of the plastic injection molding process. To achieve high process effectiveness and desired product quality, correct and precise parameter settings are essential. One of the benchmarks for assessing the productivity and efficiency of an industry is to look at the level of product defects that occur in producing a product. This article aims to provide a brief review of the explanation of injection molding, types of molding, types of injection failure, experimental methods in determining injection molding parameters. Types of failure in the injection process such as short shot, weld mark, warpage, sink mark, air trap, black spot, flashing, hole, over molding, delamination. The experimental method determines parameters such as the Taguchi method, ANOVA method, hard computing techniques. The future will likely tend to use AI techniques as has happened with other methods in manufacturing processes to complement conventional techniques in determining injection molding process parameters.

Keywords: *Plastic Injection, Injection Molding, Taguchi, ANOVA, Hard Computing Techniques, Farming Products.*

1. INTRODUCTION

In the last three decades, injection molding has experienced rapid growth due to the development of new application areas in the automotive or transportation, electronics or appliance, medical and packaging industries.[1]–[3] More than 30% of products are manufactured using the injection molding process.[4][5] However, the equipment used in injection molding can be quite expensive and sophisticated, injection molding is not suitable for small scale production.[6]–[9]

Injection molding as one of the important manufacturing techniques for plastic processing. After long-term development, this technology has become very mature with highly standardized process characteristics and mold components. In many aspects, injection molding has shown real advantages over 3D printing of plastic parts.[10][11] The injection molding process is a complex process because it involves several process steps starting with the material filling step, namely the melted plastic material will flow from the injection unit through the sprue, runner, gate and into the cavity.[12][13]

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Injection molding is one of the advanced manufacturing technologies for low-cost and reliable production processes. It includes several integrated stages namely injection, packing, cooling, and ejection.[14]–[16]

The quality of injection molding depends on material characteristics, product shape, mold design and process conditions or process parameters.[17][18] Injection molded products often have many defects, such as short shots, spray, sags, flow marks, weld marks, and floating fibers. This defect can be overcome by further processing, but it will increase costs and time.[19] Most defects are caused by improper injection pressure and temperature control. So, control over these parameters is very important in reducing defects.[20]

Injection molding process parameters such as cycle time, filling time, cooling time, injection time, injection speed, injection pressure, holding pressure, melting temperature, mold temperature and so on need to be optimized in order to produce finished plastic components with good quality.[21]

Injection molding can be a better alternative to traditional methods. Injection machine learning techniques can be used in optimizing mold design to reduce cooling rates and improve final product quality.[22]–[24]

The purpose of this research is to briefly discuss the explanation of injection molding, types of molding, types of injection failure, experimental methods in determining parameters.

2. LITERATUR REVIEW

2.1. Plastic Injection

Plastic injection is the process of forming a workpiece with the desired shape from plastic material using tools in the form of molds which in the manufacturing process use heat treatment and pressure.[25]–[27] Plastic injection is the process of forming products from plastic material with variations in shape and size.[28][29] Injection molding machines are required for injection of plastic products. To select an injection machine, it is important to determine the size of the upper clamp plate and lower clamp plate of the mold tool.[30]

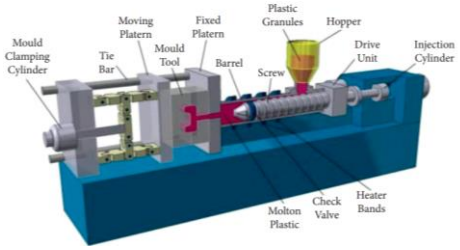

Fig 1. Plastic injection molding setup[31]

Injection molding is a melted plastic consisting of two types of polymers thermoplastic and thermoset polymer. This machine injects pressure into the mold cavity which fills and solidifies the molten plastic to produce a product. The entire injection molding process consists of three stages, namely filling, post-filling, and mold opening. Some of the attractive Properties of plastics are as follows: transparency, ability to make complex sizes and shapes quickly, ability to integrate with other materials easily with excellent thermal and electrical insulators, light weight, and injection molding is not suitable for small scale production Anti rust. Some of the issues regarding quality are flow marks, volumetric shrinkage, flowing,

weld lines, flash, sink marks, dimensional shrinkage variations, and warping. Recently, neural networks and machine learning have evolved drastically to solve problems that may occur in the injection molding process to improve its characteristicshe.[31]–[34]

There are two sources of energy in injection molding machines that act as a driving force to run an injection machine, namely: a compressed air source which functions to press the piston or plunger, and an alternating electricity source as a power source for the heating parts or heating elements.[35] The injection process can be automated, and as a result, production capacity can be significantly increased. Typically, injection molding is used in the production of smaller components.[36]

Wider parts require larger molds and more material to fill the mold, impacting production rates and efficiency. So, the speed of injection molding depends on the size and complexity of the mold. Labor costs are also drastically reduced due to the automation of injection molding. Another advantage of injection molding is that complex parts can also be molded.[37][38]

A common problem that often occurs in the plastic injection industry is shrinkage in the products resulting from the injection process. In the injection molding process there are many parameters that can influence the injection results. These parameters are holding time, injection time, cooling time, mold temperature and others. If one of the injection process parameters is ignored, the results of the molded object will not be good.[39]–[41]

Factors that influence injection molding are the plastic material used, the injection machine and the injection molding process.[42] Factors or parameters that can influence the phases in the injection molding process, namely design factors and plastic raw material factors.[43] The different properties of plastic raw materials include tensile strength, shear strength, melting point, viscosity at certain temperatures, and others. Of all these differences, the one that most influences the plastic injection process is the viscosity of a material. This viscosity affects the flow rate of material to fill the mold cavity.[44]–[46]

In the industrial world, there is increasing demand for increasing efficiency and productivity in producing a product. One of the benchmarks for assessing the productivity and efficiency of an industry is to look at the level of product defects that occur in producing a product. With a high level of product defects, an industry can be categorized as an industry with poor productivity and efficiency. This is a reference for the industrial world to further improve work systems to reduce the number of product defects so that high levels of productivity and efficiency are obtained.[47]–[49]

Table 1. Types of injection molding failures

No	Types of Failure	Description
1	Short Shot	One form of plastic injection product failure is where the injected material cannot fill the entire mold space so that the resulting product is imperfect.[50]
2	Weld Mark	It is a product defect in the form of lines on the surface of the product.[51]
3	Warpage	Warpage is a part of the product that is bent or curved, usually caused by high injection temperatures into the product.[52]
4	Sink Mark	A product defect in the form of a convex shape on the surface of the product.[53]
5	Air Trap	A type of defect where the liquid material does not fill the cavity due to air being trapped in the cavity, so that the product shape does not match the expected shape.[54]
6	Black Spot	Black spots or scratches on the product surface occur due to thermal damage. There is residual material trapped in the heater

		or product contamination by unnecessary substances which causes black spots.[55]
7	Flashing	Flashing which means there is excess material that has frozen at the edges of the product.[56]
8	Hole/Gap	Loose product defects in printed parts due to the influence of temperatures that are not hot enough.[57]
9	Over moulding	Defective cable product pushed due to too high pressure. [57]
10	Delamination	One type of layer deformation in laminated composite materials, which is caused by continuous stress and pressure on the material.[58]

3. INFLUENCE OF PROCESS PARAMETERS

3.1. Result of Main Experiment

Injection rate By increasing the injection rate, the product's tendency to produce deformation is reduced.[59] The material has a faster flow rate, resulting in more intense shear and greater molecular orientation.[60] Melting temperature As the melting temperature increases, the viscosity of the polymer melt decreases.[61] If the melting temperature is too high, the materials and parts will easily overheat and the damage will shrink drastically after cooling to room temperature.[62]

Mold temperature Mold temperature affects production efficiency and product quality.[63] Adjusting and maintaining a suitable mold temperature can effectively improve the mechanical properties, improve dimensional accuracy, improve surface quality, and reduce warping deformation and product shrinkage.[64]

Injection pressure Excessive injection pressure can cause differences in molecular orientation and the formation of residual stresses. [65] Holding time Extending the pressure holding time is beneficial to reduce the backflow of melt to the gate, improve the feeding effect, and make the product denser.[64][66]

Cooling time The melt in the cavity does not reach the ejection temperature if the cooling time is too short, and large deformation will occur after ejection.[67] On the other hand, if the cooling time is too long, the injection process will become inefficient.[68]

The holding pressure can compensate for the deformation of the product during the cooling process and can ensure the dimensional stability of the product.[69] The pressure in the mold cavity usually decreases from the filling end, causing the volume shrinkage of the polymer melt away from the gate to be greater than the volume shrinkage around the gate.[70]

4. EXPERIMENTAL METHOD FOR DETERMINING PARAMETERS

It is a better solution to develop a systematic and scientific method to determine a set of process parameters to ensure reliable product quality control in practical applications.[43] The plastik injection molding process contains dozens of process parameters such as mold and melt temperature, injection rate, injection pressure, holding pressure, holding duration and cooling. Process parameters can greatly affect product quality, especially for the problems of warp deformation and shrinkage. However, the effects of these parameters are coupled to each other and are highly dependent on the long-term experience of the skilled operator process parameters.[71]

4.1. Taguchi Method

The Taguchi design method is a proven statistics-based technique for the optimization of complex problems in many fields, including manufacturing, engineering, biotechnology, marketing and advertising.[72] One method of improving the quality of plastic products is by designing quality in the injection molding process. One method of improving quality at the design stage is robust design introduced by Genichi Taguchi.[73] Taguchi is the easiest design method to use both in terms of cost and technical implementation. The Taguchi method is a method that is quite effective in determining factors that influence a particular phenomenon or process.[74] The Taguchi method is a quality improvement effort that focuses on improving product and process design. The target of this method is to make the product insensitive to disturbance variables (noise), so it is called robust design.[75]

Compared to traditional experimental designs, the Taguchi Method utilizes a special OA design to test quality characteristics through a minimal number of experiments using the Taguchi technique via an orthogonal array (OA) to optimize injection molding.[76]

4.2. ANOVA Method

The large number of parameters analyzed makes it possible to use analysis of variance to identify important factors influencing the morphology of the mold part. One of the most commonly used statistical methods to estimate the contribution of each parameter is analysis of variance (ANOVA), which can be used to find the parameters that have the most influence on a particular response.[77]

ANOVA was carried out to determine the effect of each parameter on shrinkage and the significance of the model and each parameter with a significance level of 5% and a confidence level of 95%.[78]

4.3. Hard Computing Techniques

Hard computing in injection molding is performed using commercial software packages or optimization modules.[79] Several commercial software packages were developed many years ago with applying finite difference or finite element methods at the filling and post stages of injection mold filling. [80]

Today, many sophisticated software packages are available which can simulate, analyze and generate injection molding data based on selected input and output parameters. Many jobs use device packages such software have been reported, for example Moldflow.[81] Moldflow combined with autodesk and simulates shallow and flat thin-walled molds from polymer composites.[41] Moldflow to determine significant parameters that influence shrinkage mold components.[82]

5. CONCLUSION

The complex designs, tight quality tolerances and time constraints in today's industrial scenario clearly require optimization techniques with the ability to precisely predict the process and machine parameters used in injection molding. The combination of parameters is desired not only to ensure that product quality meets specifications but also to improve the stability of the injection molding process. Future research will likely tend to use AI techniques as has been the case with other methods in manufacturing processes to complement conventional techniques in determining injection molding process parameters. A system for setting injection molding parameters that can combine and mutually reinforce various AI technologies is waiting to be discovered.

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