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# Taguchi Method Used in Optimization of Plastic Injection Molding

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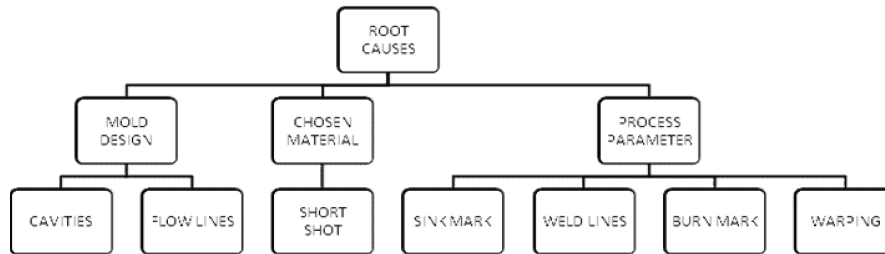
**Abstract.** Plastic Injection molding is the most important process of plastic product where it determines whether the product can be used or it has inadequacy. The inadequacy can make the product unusable or also can affect the quality of the product. So in order to avoid the inadequacy, optimization of the process parameter must be done. This is one of the steps to get the best quality of product. It will able to save cost as well as increase the quality of the product. Taguchi method is one of the methods that use to identify the parameter that can cause the defect of a product. This method is able to reduce the defect and also able to decrease the cost of creating the product.

## 1. Introduction

In each of the product, 70 % of element in consumer product is represent by mold manufacturing that is essential in all industry [1]. This process is difficult that enforced mold maker that has skill and qualification [1,2]. Today, injection molding is one of the crucial processing procedures of polymer in industry of plastic [3]. It is highly favored process in industry of manufacturing due to its availability to generate intricate-shape plastic part with high accuracy of dimension and shorter cycle times [4]. The process of molding required a proper design and material to avoid defects of the product [5]. The defect can affect the function and appearance of the product.

The defect occurs because of 3 main factors which are mold design, the chosen material and process parameter. Design of mold may cause cavities and flow lines occur on the product. Short shot is one of the defect causes by the unsuitable material. Process parameters play big roles in produce the high-quality product. Sink mark, weld lines, burn mark and warping are caused due to the process parameter. Shrinkage can be occurring on finished product that cause sink mark, short shot or warpage defect [6]. Figure 1 shows the roots causes of defect occurs on finished product.



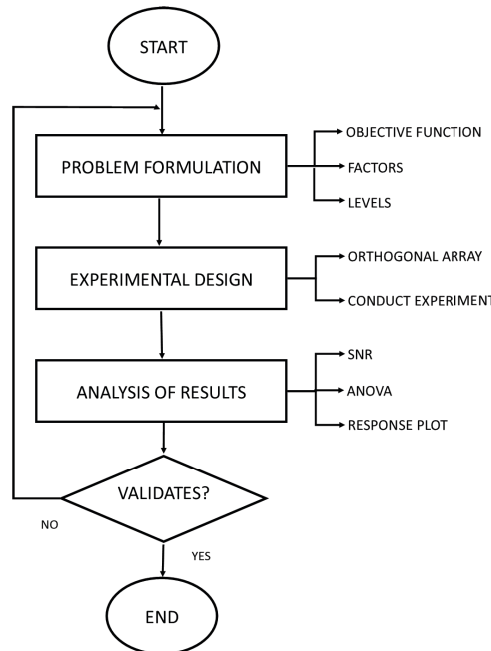


**Figure 1.** Root Causes and Defect

Shrinkage appears in most of the defect that caused by unoptimized process parameter. There are many method can be used to optimize the process parameter to minimize the defects such as Response Surface Methodology (RSM) and Taguchi method. Hatta et al [7] and Zakaria et al [8] applied the method together with ANOVA and able to get the factor that can be change to minimize the defect which are melt temperature, mold temperature, packing pressure and cooling time [7]. However, RSM need larger number of experiments in contra with the Taguchi method, which required less number of experiments. This paper will be discussed on use of Taguchi method for optimize the plastic injection molding parameter in order to reduce the percentage of shrinkage. Throughout the literature review, the general main factor that caused shrinkage is determined.

**2. Taguchi Method**

Dr Genichi Taguchi has developed a method to identify the best combination that used during the process in the manufacturing [9,10]. Taguchi method is a very effective tool that used to design and improve the high-quality system [11-15]. Industries able to decrease huge amount of time for the development of the product without adding any costs by applying this method [16,17]. Figure 2 is flow diagram that has been illustrated for a better understanding on Taguchi method.



**Figure 2.** Taguchi flowchart

The first step is problem formulation. In this step the objective function, factors and levels is defined. It needs fully understanding of the chosen process. The second step is the process of design and conduct the experiment. Based on the number of defined factors and levels, a standard orthogonal array is created and used in experiment. The next step is result analysis. In Taguchi method, three main statistical method are used in analyze the design. The three statistical methods are Analysis of variance (ANOVA), signal-to-noise ratio (SNR) and Analysis of means (ANOM)[15-17]. The last step is performing validation of experiment. For each run in the external array, there are 27 experimental runs in the internal array. By design, only one run will yield the highest profit margin. Preliminary visual inspection of trends of each factor average contributions at all levels can be made through a response plot.

### 3. Discussion

#### 3.1 Research using Taguchi method

Taguchi method has widely used as one of the optimization method in many areas. One of the areas is injections molding process. Each product has different process parameters that cause the defect due to different design of mold and different material. Each of products also has different value of process parameter depending on the design of product and material used in product. It is used the most in identifying the parameter that caused shrinkage and warpage [10,17 – 20]. This method used to reduce the number of experiment and investigate the factor that caused defect on the finished product [12].

Some researcher combines Taguchi with other method to increase the efficiency of the method. Moayyedean et al [11] implement Taguchi with FAHP and TOPSIS to increase the option in improving the quality of final product during injection molding. Khavekar et al [12] compared Taguchi with Shainin system and stated that Taguchi method consumed more number of experiment and time but its more trustworthy method in optimize the process parameter [20]. After that, the parameter must be optimizing to get the best settings. In the parameter optimization, some researcher has applied Artificial Intelligence techniques such as Artificial Neural Network [12] and some of them applied non – conventional technique which is less complicated and efficient. Most of the researcher choose naturally inspired algorithm to overcome the problem of optimizing warpage [23].

#### 3.2 Process parameter chosen by taguchi method

Process parameter of plastic injection moulding is the parameter that involved before, during and after process of injection molding. The parameter is melt temperature, mold temperature, packing pressure, packing time, cooling time, injection pressure, injection time, cooling temperature and gate location. Based on previous research, melt temperature is the most chosen parameter that causes the shrinkage on the finished product. Mold temperature, melt temperature and packing pressure are the most chosen parameter that cause the defects on the product [2, 21, 23].

The present of weldiness can be reduce by increasing the injection speed and melt temperature and lowering the injection speed [24]. Taguchi based GRA gave an opportunity to increase and enhance the parameter of injection molding process. The weld-lines and sink mark defects successful reduce by obtain the best process parameter. Melt temperature, back pressure and holding time were rank as the top three parameters that contribute the defect [25].

Packing time and cooling time were choosing as parameters that cause the warpage of the final product [26]. Taguchi together with signal-to-noise ratio and variance analysis were used to get the consequence process parameter. The parameter then applied in Kriging surrogate model to get the mathematical relationship with warpage. As the method applied on front shell of lcd tv, packing pressure and packing time are the most important parameter [27]. The application of Taguchi with ANOVA and ANN analysis enable identification of best level for each factor. The most significant factor that has been identified by the method is melt temperature, coolant temperature, and packing time [23].

#### 4. Conclusions

The Taguchi method is an old method yet it still popular in research of injection molding. It is used process of optimization of injection molding by choosing the most influence parameters which are mold temperature, melt temperature, packing pressure and packing time. This method is able to reduce the time taken in creating new product and testing it. It is able to reduce the cost and improve the quality of injection molding process. Taguchi method also provides robust design solutions. It can optimize several factors simultaneously. It can be hybrid with other method to get the best result.

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