Optimization of Injection Molding Parameters by Data Mining Method in PIM Process

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Abstract

Data Mining is a method that can be used to analyze large amount of data and produce useful information. In this study, clustering which is one of data mining tasks is used to clustered machine based on the injection moulding data. This paper is the first documented results on the optimization of Injection Moulding via Data Mining. Powder injection moulding is a process to produce near net shape with intricate part in mass production. This work focus on the optimization of injection moulding process with combination of fine, coarse and bimodal water atomized SS 316L powder particles. The parameters involved in the optimization are injection pressure, injection temperature, mould temperature, holding pressure, injection rate, holding time, powder loading, cooling time and particle size. These variables are based on the defect score, green density and green strength. The key influencer report shows that the most influencing factors are injection rate, holding pressure as well as mould temperature where defect score lower than 2.4 can be achieved. The density higher than 5.34g/cm\textsuperscript{3} is also influenced most by the mould temperature. The result also shows that the optimize condition can be achieved by using bimodal particle. Injection rate and mould temperature gives the highest impact on the defect score and green strength value. While highest green density is significantly affected by powder loading and injection pressure.

Keywords: Data mining; optimization; powder injection molding (PIM)

Abstrak


Kata kunci: Lombongan data; pengoptimuman; pengacuanan suntikan serbuk

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1.0 INTRODUCTION

Data mining is a concept which by utilizing it we can isolate significant data with unimportant data and discover hidden data relations. By using data mining techniques, useful data will be able to be detected and use them in queries so we can enhance speed of information accessibility. Data mining supports knowledge discovery by finding hidden patterns and associations, constructing analytical models, performing classification and prediction. One of the widely used tasks in data mining is clustering. Clustering as a data mining task is also called segmentation. It is used for identifying natural groups of data based on attributes specifications. Each group consist similar attributes. Iteration has an important role in clustering methods for converging of model [1].

PIM process is evolved when the world are urged for smaller scale product with complex geometry in mass production with lower cost than machining. It combines the conventional injection moulding and powder metallurgy to produce high volume with high quality, near net shape products. In PIM process, the metal or ceramic powder is mixed with binders to form feedstock and then injected to a mould, followed by debinding and sintering to produce parts. In this process, the injection moulding step is very much influenced by parameters such as injection pressure, injection temperature, mould temperature, holding pressure, injection rate and holding time [2]. Other optimization method has been done using Taguchi and Response Surface Method by other researchers [3],[4]. However, this study will apply data mining as an optimization tool. The difference of Taguchi and Response surface method (RSM) compared to data mining is data mining produce one algorithm for optimization based on results while, Taguchi and RSM has one algorithm that need to be followed before the experiment started. The data mining techniques has been widely use in manufacturing process such as automotive, LCD, semiconductor, steel manufacturing for predictive maintenance, fault detection, diagnosis, and scheduling [5]. Data mining has also been applied to find optimum condition or optimization of a process [6]. In this study the optimize parameters of injection molding process by data mining is reported. The scope of study is based on data reported and this work is focused on data optimization by data mining only.

2.0 METHODOLOGY

The optimization work was carried out based on Jamaluddin et. al. previous works [7]. They used fine and coarse water atomised SS316L powders as shown in Table 1. The powder sizes used were 15μm for large size powder, while 7μm for small size powder. The SEM image or the morphology of the powder is as in Fig. 1. The powders were mixed with 73 % PEG weight of polyethylene glycol (PEG) and 25 % weight of polymethyl methacrylate (PMMA) to produce feedstock.

The optimization parameters for the injection molding step includes injection pressure, injection temperature, mould temperature, holding pressure, injection rate, holding time, powder loading, cooling time and particle size based on defect score, green density and strength. The defect score was evaluated by surface observation, the more defect observed the more defect score value. The green density was obtained by using densimeter based on MPIF42 standard. While strength of the part was obtained by INSTRON 5567. Each feedstock was injected for 27 run and repeated 5 times [3]. The average data for each run was then used for optimization. The data were arranged as shown in Table 2.

<table>
<thead>
<tr>
<th>Particle Size</th>
<th>D10</th>
<th>D50</th>
<th>D90</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coarse</td>
<td>4.99</td>
<td>15.05</td>
<td>34.75</td>
</tr>
<tr>
<td>Fine</td>
<td>3.34</td>
<td>7.16</td>
<td>17.52</td>
</tr>
</tbody>
</table>

Data mining tools in Excel 2007 is used for data processing with an add-in facility which is SQL Server. Generally, these features acted on information tables and they are able to perform several tasks such as calculation of column influence, categorize of similar rows, the same row, forecasting based on information series and finding unlike rows in a table. The results of these tasks are able to analyze and they are presented by using charts and mining tables [8]. The relevant tools and methods for data mining process are categorized into four main groups. They are classification, clustering, association rules and regression. In this paper we used clustering as a main data mining tool. Clustering or segmentation is another data mining method. It is utilized for identifying natural data groups based on their attributes. Each group includes similar objects. Usually, clustering used unsupervised methods. And also two main tools are used for providing analytical information:

1. The Analyze Key Influencers Tool

Data dependency and data influences are able to calculate by using this tool. It analyzed the column correlations in a table depend to a target column as a result. The influence values are presented by a table. In this paper we consider Defect Score, Density and Strength as a target value and calculate the other column dependencies according to the target columns.

2. The Detect Categories Tool

This tool enables identifying natural groups in data. This is one of the most important methods for data processing which is called Clustering. By utilize clustering, information patterns or similar objects can be determined. Actually, information have categorized based on their adjective attributes. To determine similarity for two rows of a table, the sum of difference should be calculated. The differences are related to corresponding variables. The rows with fewer differences are located in the one group. We can select several variables for calculating the differences. In addition, we can define the maximum number of clusters. The result includes three parts. These outputs are general table for displaying number of objects in each cluster, descriptions of clusters by values and the visualization of data distributions in a cluster [9].

![Figure 1 Morphology of the SS316L water atomised powder [3]](image)
### 3.0 RESULTS AND DISCUSSION

Based on the key influencers report for density [Figure 3(a)], the mould temperature should be set at 63.5°C which has the most influence to increase the green density value more than 5.34 g/cm³. The highest density is achieved by using bimodal particle. In addition, the mold temperature has more impact on the density (>5.34g/cm³) compared to bimodal particle size. The injection rate at 5 ccm³/s demonstrates less significant to the density, in the range of 5.19 to 5.24. The most impact to the density between 5.19 g/cm³ to 5.24 g/cm³ is related to the fine particles as well. While as shown in Figure 3 (b), the holding pressure at 800 bar with mould temperature at 63.5°C is able to produce defect score ranging from of 3.14 -3.77 and 3-77 to 4.62 respectively.

From data mining result, the optimized condition for injection molding parameters is shown in Figure 4. Based on all results, it is obviously found that bimodal powder has an ability to increase the strength and density, on the other hand decreases the defect scores number. The smaller powders will interstiticed between the gaps of larger size powders in bimodal structure thus decreases the porosity and increase density [10].

<table>
<thead>
<tr>
<th>No</th>
<th>Injection Pressure (kPa)</th>
<th>Injection Temperature (°C)</th>
<th>Mould Temperature (°C)</th>
<th>Holding Pressure (bar)</th>
<th>Injection Rate (ccm³/s⁻¹)</th>
<th>Holding Time (s)</th>
<th>Powder Loading (%)</th>
<th>Cooling Time (s)</th>
<th>Particle size (µ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>750</td>
<td>160</td>
<td>60</td>
<td>800</td>
<td>15</td>
<td>15</td>
<td>64</td>
<td>10</td>
<td>Fine</td>
</tr>
<tr>
<td>2</td>
<td>650</td>
<td>155</td>
<td>55</td>
<td>1000</td>
<td>10</td>
<td>10</td>
<td>63.5</td>
<td>6</td>
<td>Coarse</td>
</tr>
<tr>
<td>3</td>
<td>550</td>
<td>150</td>
<td>50</td>
<td>1200</td>
<td>5</td>
<td>5</td>
<td>63</td>
<td>2</td>
<td>Bimodal</td>
</tr>
</tbody>
</table>

**Table 2** Optimization parameters for injection moulding parameters
Injection rate and mould temperature gives the highest impact on the part strength and defect score. This is in good agreement with studies done by [3]. Higher mould temperature provides the better or higher viscosity which allows the material to flow smoothly into the mould. Injection rate and mould temperature influence the mean value of part dimension [11]. Low injection can cause shrinkage, irregular injection rate can cause flow marks or jetting, while higher injection rate can cause flashing. Thereby, adequate injection rate is crucial to produce high quality injection part.

The density of injected part is significantly affected by injection pressure and powder loading. Insufficient injection pressure will cause short shot because the pressure is not enough to feed the material inside the mould. An optimum powder loading is desirable to produce high density part. This is the most preliminary study that should be done before injection moulding stage. However, the particle parameters as well as the binder used should be taken into account [12].

From data mining result, Injection pressure has no significant effect on the part strength. This statement is also mention by Rosato et al. in their handbook [13]. Cooling time is also found to have less effect on the injection moulding process.

### 4.0 CONCLUSIONS

Data mining is one of useful tool to optimize injection moulding parameters. The conclusion for optimization of 316LSS by data mining is summarized as follows:

1. Injection Temperature, Injection rate, Injection pressure and powder loading is the most significant variables that affect the injection moulding process for the highest green strength part.
2. From the key influencer density report, the most influencing factor is mould temperature. While based on defect score the most significant factors are injection rate, holding pressure as well as mould temperature.
3. Optimized moulding parameters enable to improve the part green strength and density, as well as improve quality which is verified by numerical method (Data Mining).
4. The future study of this research is to verify the optimize PIM parameters by experimental study.

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### References


