Optimization of processing conditions on mechanical properties of Polypropylene nanocomposite reinforced with Gigantochloa Scortechinii via ANOVA

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Abstract. Defining the level and value of the appropriate parameters is very significant in seeing the quality in mechanical properties of the injection molding products, particularly affecting the advanced material such as nanocomposites. Consequently, this study was aimed to optimize the processing conditions to the mechanical properties of the sample in nanocomposite polypropylene reinforced with Gigantochloa Scortechinii fiber. The tests to be tested were flexural strength, shrinkage and warpage, and the factor chosen were melting temperature, filling time, packing pressure and screw speed. The bamboo fiber types Gigantochloa Scortechinii in form nano powder, and preheat at 120°C after alkaline treatment, and so blended with polypropylene, Maleic anhydride, and cloisite 20A using two step of twin-screw extruder brabender. According the result from ANOVA, the flexural strength and shrinkage for 0wt% and 3wt% of Gigantochloa Scortechinii fiber, the most influence parameter is filling time, while the melt temperature for 6wt% of gigantochlia scortechinii fiber. For the result of warpage, for 0wt% and 3wt% of fiber Gigantochloa Scortechinii, the melting temperature is the highest factor prevailing warpage. Whereas for 6wt% of the fiber Gigantochloa Scortechinii, the packing pressure and screw speed are the highest factor. The conclusions of this study will be invaluable for quality dominance and benchmarking for future researchers.

Keywords: Injection Molding, Cloisite 20A, Gigantochlia Scortechinii, ANOVA.

1. Introduction

Today, the injection molding in polymer processing is to the highest degree in manufacturing. This is because, this competence can produce for series production and can also save time and costs. Nevertheless, the culmination of the proficiency is the optimized processing conditions to ascertain that the in demand product properties can be accomplished [1]. As far as the design of the experiment (DOE) is concerned, Taguchi Method has introduced numerous statistical methods to define the optimum parameter in addition to the greatest contributory factor in mind for the pick out reactions. In the study of the injection molding process, many researchers performed excessively using Taguchi method. Previous researchers have obviously defined how the responses and materials are affected by the parameter in processing [2,3,4,5]. Several previous searches related to the scope of this study also been carried out [7][8]. The result will be used to determine the level and the factors of the study.
An examination noted that the nanoclay, polymer, nanocomposite and natural fiber have become more unremarkably referable to the polymer and advance material are widely used and naturally plentiful with a high aspect ratio [10]. With respect to additional reference, the submitter reviewed the properties, application and the preparation of polymer nanocomposites [11]. Nevertheless, the effects of clay types, and percent distribution in the composite paying the primary role when blended with any fillers and the choice of seizing parameters have been highlighted as important to build sure the whole material is fitted to the matrix polymer in order to prevent problems properties of injected mould [12].

2. Experimental
Figure 1 illustrates the main process of experience.

![Figure 1. The frame process of the experiment.](image)

2.1 Material preparation
The composition of compounding were divided into three different composites as shown in table 1 below. The material was the raw polypropylene (PP), polypropylene grafted-maleic anhydride (PPgMA) as compatibillizer, cloisite 20A and *Gigantochilia Scortechinii* (bamboo fiber).

| Composition | PP     | PPgMA  | Cloisite 20A | Gigantochilia Scortechinii |
|-------------|--------|--------|--------------|----------------------------|
| 1           | 84 wt% | 15 wt% | 1 wt%        | 0 wt%                      |
| 2           | 81 wt% | 15 wt% | 1 wt%        | 3 wt%                      |
| 3           | 78 wt% | 15 wt% | 1 wt%        | 6 wt%                      |

The figure 2 shows the preparation of the fibers starts with clean up the bamboo using paper. The fiber was use is the whole bamboo include the skin of bamboo. Then the bamboo was chipped into small size (10cm), then the bamboo was soaked in sodium hydroxide for the treatment, this treatment was commonly used is alkaline treatment. After the treatment, the bamboo is dry under the sun in naturally before using dry oven at 120°C for 6 hours. The Granulator machine was used to crush the bamboo into powder (nano size) as shown below.
2.2 Design of the experiment
The injection molding machine was used is types Nessei NP7-1F which is the education scale machine. By using the mould for standard ISO D790 for flexural strength, the sample was prepared regarding the formulation respectively. By using Taguchi Method, the effect of several parameters most effectively to determine in using the orthogonal array (L₉3⁴) and the details was prepared at table 2. This method was best used to find optimal process values to improve product quality. Four factors of processing condition were chosen with 3 different levels and bring out 27 samples for the 9 trials of sample have been tested.
2.3 Measuring of flexural strength
The flexural strength of the specimen was measured using a universal test machine (10KN) based on three bending points according to ISO 178 standard with the speed of 2.04317 mm/min.

2.4 Determination of warpage and shrinkage.
Warpage and shrinkage were bound together. The different shrinkage is occurred by the deformation. The defect happens due to numerous factors and parameters which were high screw pressure, melting temperature and filled time rate is overly low and partially turnout is excessively hot [1]. The shrinkage and the warpage were selected for optimisation by checking the injection molding setting. These superiority features were measured in samples following injection molding. The sample that was ejected from the mould must be cleaned of the runner and flashing prior to measuring the sample. The shrinkage was measured by means of the equations (1) and (2), the coefficient thermal expansion (α) is the value of tool steel by value (6.45×10⁻⁶/°F) and the symbol $T_{mould}$ is refered to temperature of mould. While, $T_{ambient}$ is referred the ambient temperature.

\[
L_C = L[1 + \alpha (T_{mould} - T_{ambient})] 
\]
\[
S = \frac{L_C - L_M}{L_C} 
\]

Subsequently, to obtain the data needed to deform a specimen, the equation (3) is used. Relates to the plate maximum and is the average thickness of the plate.

\[
Z = h - t_a 
\]

2.5 Measuring the ANOVA
ANOVA has been used to provide the variance measure level. It determines the variability (variance) of the data using the Minitab software.

3. Result and discussion
3.1 Flexural strength
Table 3 shows the ANOVA result of the flexural strength for 0wt.%, 3wt.%, and 6wt% of Gigantochlia Scortechinii fiber. The calculation is based on the outcome of the S/N ratio.
Table 3. The flexural strength results of ANOVA for 0wt.% ,3wt.% and6 wt.% of Gigantochlia Scortechinii fiber.

| Parameter          | Flexural Strength 0 wt.% GS fiber | Flexural Strength 3 wt.% GS fiber | Flexural Strength 6 wt.% GS fiber |
|--------------------|-----------------------------------|-----------------------------------|-----------------------------------|
|                    | Seq SS | Adj SS | P%  | Seq SS | Adj SS | P%  | Seq SS | Adj SS | P%  |
| Melting Temperature (A) | 0.0374 | 0.0374 | 15.5 | 0.05863 | 0.05863 | 35.84 | 0.261 | 0.261 | 31.84 |
| Packing Pressure (B)   | 0.0073 | 0.0073 | 3.04 | 0.00873 | 0.00873 | 5.34 | 0.1628 | 0.1628 | 19.86 |
| Screw Speed (C)        | 0.0073 | 0.0073 | 3.04 | 0.00873 | 0.00873 | 5.34 | 0.1628 | 0.1628 | 19.86 |
| Filled Times (D)       | 0.1891 | 0.1891 | 78.42 | 0.08751 | 0.08751 | 53.48 | 0.2332 | 0.2332 | 28.45 |
| Total                | 0.2412 | 100 | 0.1636 | 100 | 0.8198 | 100 |

According to Table 3, In the result of 0 wt.% of Gigantochlia Scortechinii fiber, the largest percent contribution was (D) filling time to 78.42% and followed by (A) melting temperature to 15.5%. The lowest percent was (C) screw speed and (B) packing pressure was 3.04%. At 3%wt.% of Gigantochlia Scortechinii fiber, the highest filling time setting (D) of 53.48%, the lowest setting was packing pressure (B) and filled time (C) of 5.34% for both parameters. Other parameters representing the melting temperature (A) at 35.84% were the most important to effect the flexural strength of the sample. The highest factor of 6 wt% sample of the flexural strength result is the melting temperature (A) followed by the Screw speed (C) 28.45%, filling time setting (D) at 31.84% and the the lowest percent contribution are packing pressure setting (B) at 19.86%. As regards the percentage of the value, it

![ANNOVA Result for Flexural Strength](image_url)
appears that all injection molding processing conditions have contributed to the findings of this research. According to Elsabbagh, et al. [13] the collective of the holding pressure of injection molding could improve the composites mechanical properties. This was in line for to the resulting crystalline the molecular chains in the polymer and the orientation of the fibers. In contrast, the increase in temperature in injection and filling times during the processing contributed to strength less of the mechanical performance in composite.

3.2 Shrinkage

Table 4 shows the ANOVA of shrinkage result for all Gigantochlia Scortechinii fibers by wt%. The calculation is based on the result of the S/N ratio.

Table 4. The shrinkage results of ANOVA for 0wt.% , 3wt.% and 6wt.% of Gigantochlia Scortechinii fiber.

| Parameter          | Shrinkage 0wt% Gigantochlia Scortechinii fiber | Shrinkage 3wt% Gigantochlia Scortechinii fiber | Shrinkage 6wt% Gigantochlia Scortechinii fiber |
|--------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|
|                    | Seq SS | Adj SS | P%   | Seq SS | Adj SS | P%   | Seq SS | Adj SS | P%   |
| Melting Temperature (A) | 0.2109 | 0.2109 | 6.19 | 2.934  | 2.934  | 8.08 | 5.8958 | 5.8958 | 55.1 |
| Packing Pressure (B)   | 0.8779 | 0.8779 | 25.72 | 6.995  | 6.995  | 19.25 | 0.8611 | 0.8611 | 8.03 |
| Screw Speed (C)        | 0.8779 | 0.8779 | 25.72 | 6.995  | 6.995  | 19.25 | 0.8610 | 0.8610 | 8.03 |
| Filled Times (D)       | 1.4464 | 1.4464 | 42.37 | 19.411 | 19.411 | 53.42 | 3.1011 | 3.1011 | 28.93 |
| Overall              | 3.4132 |       | 100  | 36.335 |       | 100  | 10.719 |       | 100  |

Figure 4. The graph of the shrinkage for all wt.% of GS.
Table 4 presents the result of the shrinkage for all wt.% of *Gigantochlia Scortechinii* fiber. At 0 wt%, the highest percentage are (D) filling times by 42.37%, whereas the (A) melt temperature at 6.19%. Other parameter appears to contribute moderately to these percent values for (C) screw speed and (B) packing pressure by 25.72%. At 3 wt% *Gigantochlia Scortechinii* fiber, the percent contribution for injection molding parameters indicates the (D) filling times the highest percent contribution of 53.42%. The (A) melt temperature was the lowest figure at 8.08% and for packing pressure (B) and screw speed (C) appear to be a moderate contributor was 19.25%. Then for the resulting sample 6 wt% *Gigantochlia Scortechinii* fiber, (A) melt temperature is the highest percentage contribution at 55.1% and followed by (D) filling times at 28.93%. The lowest value is 8.03% of (C) screw seed and (B) packing pressure was the lowest at. As regards the percent contribution for all parameters are interrelated with each other in the injection molding process. From the Hilmi *et al* [7] was agreeing the factor of melt temperature is rather less in effect on the shrinkage. Nevertheless, the researcher Altan *et al* specified that the melt temperature was considered more significant than the holding pressure to minimizing the defect of shrinkage [14]. According to the researcher, to get the optimum result for the shrinkage is difficult to discover, this is because it depends on the types and the composition of materials has been used.

### 3.3 Warpage

Table 5 shows the warpage ANOVA result for all wt.% of *Gigantochlia Scortechinii* fiber. The calculation is based on the result of the S/N ratio.

| Parameter | Warpage 0 wt% | Warpage 3 wt% | Warpage 6 wt% |
|-----------|---------------|---------------|---------------|
|           | Gigantochlia Scortechinii fiber | Gigantochlia Scortechinii fiber | Gigantochlia Scortechinii fiber |
| Melt Temperature (A) | 173.14 | 72.21 | 5.195 | 5.195 | 39.09 | 1.9330 | 1.9330 | 10.67 |
| Packing Pressure (B) | 12.79 | 5.33 | 2.766 | 2.766 | 20.81 | 8.0540 | 8.0540 | 44.44 |
| Screw Speed (C) | 12.79 | 5.33 | 2.766 | 2.766 | 20.81 | 8.0540 | 8.0540 | 44.44 |
| Filling Times (D) | 41.06 | 17.13 | 2.564 | 2.564 | 19.29 | 0.0810 | 0.0810 | 0.45 |
| Total | 239.78 | 100 | 13.291 | 100 | 18.122 | 100 |

In accordance with table 5, at 0 wt% *Gigantochlia Scortechinii* fiber, the (A) melt temperature parameter contributes to 72.21% as the highest percentage, while the (C) screw speed and (B) packing pressure were the bottommost at 5.33%. The (D) filling time appears to contribute moderately at 17.13% intakes. The result at 3 wt% of *Gigantochlia Scortechinii* fiber indicates that the uppermost percentage with 39.09% was the (A) melt temperature and the lowest is (D) filling time at 19.29%. The parameter of (C) screw speed and (B) packing pressure appears to make a moderate contribution at 20.81%. The last is 6 wt% of *Gigantochlia Scortechinii* fiber, the highest percentage was (C) screw speed and (B) packing pressure at 44.44%, the (D) filling time was the lowest at 0.45% and the (A) melt temperature is the amongst at 10.67%. Based on the result, 6 wt% of *Gigantochlia Scortechinii* fiber notes that the value of packing pressure for warpage also has the highest in the result of ANOVA. According to researcher
oktem.H in his finding was stated the packing pressure is the most important parameter need to control to minimize the warpage.

4. Conclusion
ANOVA was applied to find deviations in the middling performance of each material tested. Consequently, the melting temperature is the most significant setting for 0% wt.% of *Gigantochlia Scortechinii* fiber on the minimum the warpage. Whereas for flexural strength and shrinkage is filling time. Next, for 3 wt% of *Gigantochlia Scortechinii* fiber shows the melt temperature parameter is the significant factor. While for flexural strength and shrinkage is filling time. For 6 wt.% of *Gigantochlia Scortechinii* fiber, the most important parameters for warpage were packing pressure and screw speed. While, for the flexural strength and shrinkage is melting temperature. Based on hilmi et al., The major cause of deformation is commonly known as the variance of shrinkage to the injection process in the case of thin walled parts of plastic. The properties of material, the geometry of the parts and the conditions of the injection molding process are classified as factors influencing variations in the withdrawal of parts during injection molding. The ANOVA analysis, with the highest percentage of the quality endpoint, provided the best sample. In a conclusive way, the objective if this study were achieved for the parameters that influence flexural strength, shrinkage and warpage. Other than that, to make the effect of the increasing in the quality of bamboo fiber (*Gigantochlia Scortechinii* fiber) in the composition also be accomplished by changing the optimal setting with respected to the parameters that result from the combination of the best setting. After completing this experiment, valuable experiences from different aspects are acquired. These have been field tested on the injection moulding machine and also include the running cycle of the injection moulding machine. This will provide better information on how to use other machines that have not been used.

![ANOVA Result for Warpage](image_url)

**Figure 5.** The graph of the warpage for all wt.% of GS.
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