THE EFFECT OF INJECTION MOLDING PROCESSING CONDITIONS AND FIBER CONTENT TOWARDS THE PROPERTIES OF POLYPROPYLENE-NANOCLAY NANOCOMPOSITES BLEND WITH *GIGANTOCHLOA SCORTECHINII* FIBERS

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ABSTRACT

Nowadays, plastics injection molding has been in high demand. In this study, the Taguchi method is used to obtain the optimum processing conditions. The designs that are used of injection molding $L_9 3^4$ of the 9 trials, 3 levels, and 4 processing conditions as factors. Processing conditions selected were melt temperature, packing pressure, screw speed and filling time. At first, (GS) *Gigantochloa Scortechinii* has to be heated at a temperature 120 °C then mixed with polypropylene, maleic anhydride modified polypropylene oligomers (PPgMA) and nanoclay according to fixed measure. Mixing process was performed using a twin screw brabender mixer machine. Next, forms of grain were produced using Plastic Granulator machine for use in the injection moulding process. In order to obtain the data of flexural strength, shrinkage and warpage, the measurement process and flexural strength tests were done. As a result, the minimum value of warpage was 0.003 mm, shrinkage of 0.00048 mm and maximum flexural strength was 36.3390 MPa. To get the best results for flexural strength, the highest value while for warpage and shrinkage, the lower is the best value. For ANOVA analysis, the quality of the highest percentage indicated the parameters that produce the best specimens. In conclusion, the objective of this study has been achieved with parameters that influenced the warpage, shrinkage, and flexural strength. Besides that, in the composition of GS would influence the percentage of injection moulding with setting for the warpage A1B3C3D1, shrinkage A2B1C1D3 and flexural strength A1B2C2D2.

ABSTRAK

Rengacuan suntikan plastik telah menjadi permintaan tinggi sekarang ini. Dalam kajian ini, kaedah Taguchi telah digunakan untuk mendapatkan keadaan pemprosesan yang optimum. Reka bentuk yang digunakan untuk mencetak suntikan $L_9 3^4$ dari 9 percubaan, 3 peringkat dan 4 syarat pemprosesan sebagai faktor. Keadaan pemprosesan yang telah dipilih adalah suhu lebur, tekanan pembungkusan, kelajuan skru dan masa pengisian. Pada mulanya, (GS) *Gigantochloa Scortechinii* dipanaskan pada suhu 120 °C, kemudiannya dicampur dengan polipropilena, oligomer polipropilena yang diubahsuai maleik (PPgMA) dan *nanoclay* mengikut ukuran tetap. Proses pencampuran dilakukan menggunakan mesin pengadun skru brabender kembar. Seterusnya, bentuk bijirin dihasilkan menggunakan mesin Granulator Plastik untuk digunakan dalam proses pengacuan suntikan. Untuk mendapatkan data kekuatan lenturan, pengecutan dan perledingan, proses pengukuran dan ujian kekuatan lenturan telah dilakukan. Hasilnya, nilai minimum perledingan adalah 0.003 mm, pengecutan 0.00048 mm dan kekuatan maksimum lenturan adalah 36.3390 MPa. Untuk mendapatkan hasil terbaik untuk kekuatan lenturan, nilai tertinggi sementara untuk perledingan dan pengecutan, yang lebih rendah adalah nilai terbaik. Untuk analisis ANOVA, kualiti peratusan tertinggi menunjukkan parameter yang menghasilkan spesimen terbaik. Sebagai kesimpulan, objektif kajian ini telah dicapai dengan parameter yang mempengaruhi perledingan, penyusutan, dan kekuatan lenturan. Di samping itu, dalam komposisi GS akan mempengaruhi peratusan pengacuan suntikan dengan penetapan untuk perledingan A1B3C3D1, pengecutan A2B1C1D3 dan kekuatan lenturan A1B2C2D2

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LIST OF SYMBOLS AND ABBREVIATIONS

A	Melt Temperature
B	Packing pressure
C	Screw Speed
D	Filling Times
BF	Bamboo Fiber
GS	*Gigantochloa Scortechinii*
NC	Nanoclay
PP	Polypropylene
PPgMa	Polypropylene grafted maleic anhydride
S	Shrinkage
S/N Ratio	Signal to Noise to ratio
wt.%	Weight percentage
Z	Warpage

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CHAPTER 1

INTRODUCTION

Introduction

Injection moulding is one of the methods that were highly regarded in the industry. This is because, this method is able to go through bulk production, time saving as well as cost effective. In this study, the method of injection moulding using machine NESSEI NP7-1F as the primary method for producing a flexural shaped (bar) of specimens. The materials used in this study are polypropylene (PP), Nanoclay (NC), maleic anhydride-modified PP oligomer (PPgMA) and bamboo fiber (BF). Polypropylene, nanoclay and PPgMA are available in Polymer and Ceramic Laboratory at UTHM. Bamboo fibers that are used are one of the types of bamboo that is *Gigantochloa Scortechinii* in Malay called "buluh semantan".

In this study, factors that should be reviewed are the processing conditions using the Taguchi Method on flexural strength, shrinkage and warpage. Taguchi Method used in this study is $L_9 3^4$ (9 trials, 3 levels, 4 factors). Four factors of processing conditions that need to be tested against include flexural strength, shrinkage and warpage. To evaluate the optimal values of the process in order to improve the quality characteristics. Processing conditions that will be performned are melt temperature, packing pressure, screw speed and filled time.

The materials used to form the specimens had underwent several methods before used as pallets in the injection moulding. The composites were determined by using the formulation 0, 3 and 6 wt.% of fiber. Then it is mixed using twin screw brabender machine and subsequently formed into pallets using granulator cutter machine.

Specimens derived from a formula used in the experiments to collect data. There are 27 samples of different mixture of material percentage has been tested with using the signal to noise ratio , means effect and analysis of variance. The tests are replicated 9 times using the Taguchi Method Orthogonal Array.

Signal to Noise ratio will examine the reliability of bending without breaking a specimen and as well as reducing the shrinkage and warpage properties of specimens. Analysis of Variance were designed to investigate four types of processing conditions were selected to find out whether it is significantly affected quality characteristics.

This study aimed to achieve high produce strength that effect more than four processing conditions that has been selected against the flexural strength, shrinkage and warpage. In additional, it is also to test the durability of bamboo fiber based formula (wt.%) on the flexural strength, shrinkage and warpage properties. In addition, this study also aimed towards optimizing the model and production setting for the injection parameters of mold.

Problem Statement

In the plastics industry, strengths and defects are crucial elements that need to be focus in producing the product with good quality and condition. In this research, to investigate the effect of using Gigantochloa Scortechinii and nanoclay in minimized defect such poor flexural strength, shrinkage and warpage are ensured. A control by monitoring and optimizing the processing condition is essential in injection moulding pre-production process. Processing conditions setting such as melt temperature, packing pressure, screw speed and filled time should be rectified earlier before mass production is carried out. Without proper information, the determination of settings shall depend on the technical experience with trial and error method.

Objectives

The objectives of this research are listed as follows:

a) To investigate the effect of formulation wt.% of fiber and the suitable processing condition through preliminary experiment toward flexural strength, warpage and shrinkage.
b) To determine the optimal injection moulding processing conditions via the Taguchi Optimization Method for the prepared sample.
c) To analyze the effects of injection moulding processing condition and fiber content via ANOVA.

Scopes of Study

The material which are chosen for this project are polypropylene (homopolymer) Titan Pro 6331 from Lotte Chemical Titan (M) Sdn. Bhd., nanoclay (20A), maleic anhydride modified polypropylene oligomers brand is OVEREC ® CA100 and bamboo fiber (*gigantochloa scortechinii).* All properties subjected to the specification and material data sheet provided by manufacturer. There is a formula that needs to be applied to conduct this study. By using the formulation of 0, 3 and 6 wt.% of fibers has been preheated at 120 °C. The procedure continues to mix process using twin screw brabender machine. The mixtures were transferred into Granulator machine for palletizing. These pallets are then used as feedstock for injection moulding process in preparation of test samples for flexural strength, shrinkage and warpage measurement.

The composites were fabricated by using injection moulding and the selection of parameter setting are referring to the injection moulding machine available at FKMP laboratory UTHM. Then, the design was done according to Taguchi Method. The parameter were set prior to filtration. A trial run will be conducted by using pure Polypropylene, to select the most influential parameter setting. Four parameter setting shall be selected because the Taguchi design which has been chosen for this experiment is $L_9 3^4$ (9 trials, 3 levels and 4 factors) parameter setting. Finally, the confirmation run werer conducted and error percentage measured by using Analysis of Variance (ANOVA).

Significant of Study

The outcomes of this study shall be beneficial in terms of providing reference for future manufacturing process. by determining the effect of processing conditions and which fiber content provide the optimum quality performance. The results can be a guidance for improvement and reliability extension to the product that utilized this process and materials.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter focuses on the previous works related to this project at which it synopsizes the related works . Previous research findings related to optimization of injection moulding processing condition and research about polypropylene-nanoclay and fiber has also been discussed in this chapter. Research on the application of polypropylene, especially at maximum flexural strength, and minimum of warpage and shrinkage were concluded at the end of this chapter.

2.2 Polypropylene-Nanoclay- Composites

Composite material is the most advanced and adaptable engineering material The matrix gives a composites its shape, surface appearance, environment tolerance and overall durability while the fibrous reinforcement carries most of the structural loads, thus giving a macroscopic stiffness and strength (Tewari *et al.*, 2012).

A composite material typically consists of one or more fillers (fibrous or particulate) in a certain matrix. A carbon fiber composite is one in which at least one of the filers is composed or carbon fibers, short or continuous, unidirectional, or multidirectional, woven, or non-woven.

2.2.1 Polypropylene

Polypropylene is one of the types of polymer. These materials were used in this study. is a synthetic resin built up by the polymerization. Polypropylene is used in many plastic products in which it has many advantages such as toughness, flexibility, light weight and heat resistance required (Chafidz, *et al.*, 2011). It is also not decomposed by water and the moisture regain is too much less, so it is negligible to count. Polypropylene is also known as a non-toxic substance and does not get stained very easily. It can be easily too fabricated, and it also can retain it stiffness and flexibility intact event at very high temperatures. The melting point of polypropylene is very high compared to other plastic. It can hold until 320^{o}F (160^{o}C). There is some example that has been made using polypropylene, such as dishwasher-safe food container. When used with hot water to wash the food container, it will not cause the dishware from warping (Bettini *et al.*, 2010). Table 2.1 and Table 2.2 show the physical and chemical properties of polypropylene.

Table 2.1 : Physical Properties of Polypropylene (Herrera-Franco & Valadez-González, 2004)

Physical Properties of Polypropylene	
Density	0.91 gm/c.c
Elongation at break	10-45 %
Elasticity	Very Good
Moisture Regain (MR%)	0
Resiliency	Good
Melting Point	170^{o}C
Ability to Protest Friction	Excellent
Color	White
Ability to Protest Heat	Moderate
Luster	Bright to Light
Tenacity	3.5-8.0 gm/den

Table 2.2 : Chemical Properties of Polypropylene (Herrera-Franco & Valadez-González, 2004)

Chemical Properties of Polypropylene	
Acids	Excellent protesting ability against acids
Basic	Basic does not affect the basic
Effect of Bleaching	Enough ability to prevent the harmful action of bleaching agent under 65ºC
Organic Solvent	Does not cause harm to polypropylene during action.
Protection Ability Against Light	It loses energy by sunlight
Protection Ability Against Mildew	Good
Protection Ability Against Insects	It does not affect by insects
Dyes	It difficult to dyes because its moisture regain is 0%

Melt processing of polypropylene can be achieved via extrusion and molding by using injection moulding machine to fabricate. Polypropylene is readily polymerized in bulk, that is in the liquid monomer itself. The liquid propylene is continuously metered to the polymerization reactor along with a high-activity / high-stereo specificity catalyst system. Polymerization temperatures are normally in the range 45-80 °C with pressure sufficient to maintain propylene in the liquid phase in range 250-500 psi that is 1.7 – 3.5 Mpa (Yan *et al.*, 2011). Table 2.3 shows the properties of polypropylene from the previous study. The researcher stated density, temperature, and the injection pressure for polypropylene.

Table 2.3 : The Properties of Polypropylene (Yan *et al.*, 2011).

Density	1.145 g/cc
Temperature	200 ^{0}C
Injection Pressure	54.4Mpa

2.2.2 Compatibilizer

There are many types of manufacture for this material. According to (Bettini *et al.*, 2010). Polypropylene Maleic anhydride-modified oligomer (PPgMA) and clays modified by octadecylemmonium for the purpose of evaluating the effect of the amount of the grafted compound the polypropylene on the mechanical properties. Around those thermoplastic, polypropylene need those strongest Growth in the reality showcase materials because of its blending from claiming properties What's more low cosset. Since polypropylene doesn't incorporate At whatever polar one assembly done its backbone, the shaping about polypropylene nanocomposites requests with make Awhile ago compatibilized. Those all approach to enhancing those similarity about polypropylene for organically changed clays need been s were as about polar utilitarian aggregations of the polypropylene polymer (Bettini *et al*., 2010).

Polypropylene Maleic anhydride grafted (PPgMA) was used as a compatibilizer to improve the dispersability of the clay. Polypropylene nanocomposites have been prepared via direct melt intercalation by using an internal mixer and a co-rotating twin screw extruder. The degree of dispersion is improved by incorporating a polypropylene maleic anhydride grafted (PPgMA). However, this improvement is obtained for concentrations of PPgMA higher than 10 wt.% (Lertwimolnun & Vergnes, 2005). By using some modification, it can improve composite properties. Coupling agents improve polymer composite properties by providing a chemical linkage between the polymer matrix and filler, improving polymer properties like moisture resistance and impact strength. The researcher Sombatsompop & Chochanchaikul (2005) was stated generally, tensile strength and Young's modulus of fibers increase with increasing cellulose content. Another finding was stated that the mechanical strength of fiber composites could be lower than the neat PVC if an appropriate coupling agent is not used due to poor interfacial bonding between natural fibers and PVC. PPgMA has been reported as one of suitable coupling agents for natural fiber reinforced PVC composites (Wirawan, *et al*,.2009). With PPgMA treatment, the strength of composite is increasing with the increasing of fiber content. In a previous work (Sathishkumar *et al*,.2013), various coupling agents were used for bamboo/HDPE (high-density polyethylene) composite and the malleated polyethylene (PEgMA) was proven to be the most effective. That is showed the couple agent was improved the strength of materials. In this study PPgMA was used because the polymer using in this study was polypropylene.

Traditionally, polypropylene grafted maleic anhydride works with PE (polyethylene) and PP (polypropylene) matrices. But, there are some works that are still in developing to use PVC matrices that may help reduce water absorption and increase dimensional stability of wood-plastic composites (Nadiah & Hamid, 2012).

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