INJECTION MOULDING PARAMETERS AND PERFORMANCE OF RICE HUSK-HIGH DENSITY POLYETHYLENE COMPOSITE

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To my beloved husband (Mohd. Yusof Hamzah) and my parents.

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ABSTRACT

A column end cap part was produced from a two stages process. The first stage was the compounding of rice husk and HDPE into pellet size and the second stage was moulding it into a product. Four sizes of rice husk were used at various compositions. The size ranged from 500 µm and below (coded as A, B, C and D) while the content of rice husk as the filler in the composite varies from 30, 40, and 50 percent of weight. A fixed amount of compatibilizer and lubricant were used. From the various compositions, only one formulation was selected for further analysis, based on the injection moulding processability and the strength of the material. The melt flow rate above 4 g/10 min was used to be the lower limit for injection moulding process. The best impact strength was the priority in the composite selection. A composite at 30 weight percent rice husk size A (RH30PEA) was found to have optimum rheological properties with respect to strength, thus used in the injection moulding process. An optimum condition was determined for the processing parameters involve melt temperature (180 °C), injection pressure (60 kg/cm^2), screw speed (240 rpm), screw backpressure (15 kg/cm^2), holding time (6 sec), cooling time (42 sec) and mould temperature (30 °C) using the Taguchi Method. The dimension of column end cap was taken as the quality measurement in the determination. The performance of the column end cap product was evaluated after the exposure to environment, accelerated UV aging and water. The impact strength experienced gradual drop with the time of exposure to environment, UV aging and water but not significantly affect the performance of the column end cap. The product absorbed less percentage of water compared to the conventional wood. The properties exhibited by the column end cap showed the advantage of using RHPE composite in the construction industry.

ABSTRAK

Profil tiang yang berongga memerlukan penutup hujung bagi mengelakkan penakungan air. Penutup hujung tiang dihasilkan melalui dua peringkat proses. Peringkat pertama adalah dengan proses penyebatian serbuk sekam padi dan HDPE ke saiz butiran dan peringkat kedua ialah pengacuannya ke bentuk produk akhir. Empat saiz sekam padi telah digunakan pada setiap komposisi. Saiz ini berjulat di antara 500 µm dan ke bawah (dikodkan sebagai A, B, C dan D) manakala kandungan pengisi sekam padi di dalam komposit ini meliputi dari 30, 40 dan 50 peratus berat. Jumlah bahan pengserasi dan pelincir adalah pada kadar yang tetap. Daripada komposisi yang pelbagai ini, hanya satu formulasi yang telah dipilih untuk analisis selanjutnya. Pemilihan ini berdasarkan kesesuaian proses pengacuan suntikan serta kekuatan bahan setelah membentuk produk. Kadaralir lebur sebanyak 4 g/10 min digunakan sebagai had minimum untuk memilih bahan ini. Selain itu kekuatan hentaman yang terbaik menjadi keutamaan dalam pemilihan komposit. Komposit yang mengandungi 30 peratus sekam padi bersaiz A (RH30PEA) didapati memiliki sifat reologi yang optimum apabila berkadaran dengan kekuatan, lalu membolehkannya untuk diacuankan. Parameter proses yang optimum seperti suhu leburan (180 °C), tekanan suntikan (60 kg/cm^2), kelajuan skru (240 rpm), tekanan belakang skru (15 kg/cm^2), masa penahanan (6 sec), masa penyejukan (42 sec) dan suhu acuan (30 °C) ditentukan dengan kaedah Taguchi. Pengukuran dimensi penutup hujung tiang diambil dalam penentuan kualiti. Ketahanan produk ini dinilai setelah pendedahan kepada persekitaran, pecutan sinar ultra lembayung (UV) serta air. Kekuatan hentaman mengalami penurunan dengan masa pendedahan namun kesannya tidak ketara. Produk ini juga didapati kurang menyerap air berbanding kayu biasa.

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LIST OF SYMBOLS

HDPE	-	high density polyethylene
PP	-	polypropylene
PVC	-	polyvinyl chloride
RHPE	-	rice husk-high density polyethylene
CECap	-	column end cap
LTC	-	lignocellulosic-thermoplastic composite
RH (A)	-	rice husk size 250-500 μm
RH (B)	-	rice husk size 125-250 μm
RH (C)	-	rice husk size 63-125 μm
RH (D)	-	rice husk size less than 63 μm
RH30PEA	-	rice husk-HDPE composite with 30 weight percent filler size A
T_g	-	glass transition temperature
$T_{process}$	-	processing temperature
$T_{degradation}$	-	degaradation temperature
T_k	-	minimum cooling time
F_o	-	Fourier number
α	-	thermal diffusivity
h	-	part thickness
T_w	-	mould wall temperature
T_e	-	ejection temperature
^oC	-	degree of Celsius
M_1	-	mass of pycnometer

M_2	-	mass of pycnometer with water
M_3	-	mass of pycnometer with specimen
M_4	-	mass of pycnometer with water and specimen
ρ_w	-	density of water at ambient temperature (23 °C)
MFR	-	melt flow rate
DSC	-	Differential Scanning Calorimetry
TGA	-	Thermogravimetric Analysis
SEM	-	Scanning Electron Microscopy
Z	-	zone
D	-	die
MINT	-	Malaysian Institute for Nuclear Technology Research
ρ	-	density
m	-	mass
v	-	volume
A	-	weight of the sample in air
B	-	weight of sample in water
ρ_o	-	density of water at the tested temperature
T_m	-	melting temperature
T_c	-	crystallization temperatures
ΔHf	-	enthalpy change of heating
ΔH_c	-	enthalpy change of cooling
MFE	-	Mean Failure Energy
h	-	constant height
w	-	mean-failure mass
f	-	factor for conversion to joules (9.80665×10^{-3})
MFM	-	Mean Failure Mass
w_o	-	smallest mass at which an event occurred
d_w	-	increment of tup weight, kg,
A	-	$\Sigma^{k}_{i=0}\, in_i$
i	-	counting index, starts at h_o or w_o

n_i	-	number of events that occurred at h_i or w_i
N	-	total number of failures or non-failures, whichever is smaller.
ΔE_{ab}	-	colour changes
TG	-	thermogravimetric
DTG	-	derivative thermogravimetric
HDT	-	heat distortion temperature
MSFE	-	Minimum Significant Factor Effect
XEE	-	estimate of experimental error
Sd	-	standard deviation
df	-	degree of freedom
k	-	sample size measured
N	-	number of runs
σ	-	confidence level
LCL	-	Lower Control Limit
CCL	-	Control Centre Line
UCL	-	Upper Control Limit

CHAPTER 1

INTRODUCTION

1.1 Introduction

As we approach the 21st century, there is a great awareness of the need for materials in an expanding world population and increasing affluence. At the same time, we are also facing problems such as the lack of landfills area, our resources are being used up, our planet is being polluted, that non-renewable resources will not last forever, and the need for environmental friendly materials.

Composite materials made from plant fibres are receiving a great deal of attention today since they are considered to be an environmentally friendly resource (Rowell, 1998). This revolutionary product, lignocellulosic-thermoplastic composite (LTC) is a combination of any type of natural fibre or wood waste and polymers, such as polyethylene (PE), polypropylene (PP) and polyvinyl chloride (PVC) in powder/ pellet form or regrind, including additives, colourants, lubricants and binders (Clemons and Ibach, 2004). LTC technology has been around for a quarter of a century, but it has gone unnoticed, largely due to a lack of demand. However this situation is changing with new design possibilities being offered in this fashionable marriage of materials (Anonymous, 2002).

In Malaysia, research on the lignocellulosic-thermoplastic composite is currently done by a few research institutes. But most of the studies are focusing toward blending and material study. No matter how good the result of the material, it is priceless if the material could not be turned into commercial products (Wee, 2002).

Recently a company based in Ipoh, Perak of Malaysia, has successfully produced an advanced composites material by compounding the cellulosic-short fibre in the High Density Polyethylene (HDPE) matrix. This composite material is extruded to profile shape, which looks exactly like a high-strength wood bar: in terms of dimension, colour, and hardness (Fibersit, 2003). Rice husk is being used up to 80 percent by weight as the reinforcing fibre in this composite material, which designed and engineered to yield performance properties superior to that of traditional wood. The Fibersit Technology composite is claimed to have all the structural qualities of wood, handles like wood but yet is stronger and more durable than wood. It can be nailed, screwed, drilled, sawn, milled, processed and finished just like wood.

However, this Fibersit Technology is only applicable in extrusion processing which means, only for a very limited dimension of product. On the account of this, Ministry of Science, Technology and Innovation (MOSTI) Malaysia has granted a fund under the Intensification of Research in Priority Areas (IRPA) Programme at Universiti Teknologi Malaysia, Skudai, Malaysia to conduct a research which inspired by the Fibersit Technology.

The information presented in this thesis is part of the ongoing research to study on the technique of producing rice husk-HDPE (RHPE) composite and the capability of injection moulding process to produce the column end cap (CECap) part from the material. As in Figure 1.1, the CECap part was selected as the end-product since it can be applied on top of the Fibersit column and at the same time complete up the design.

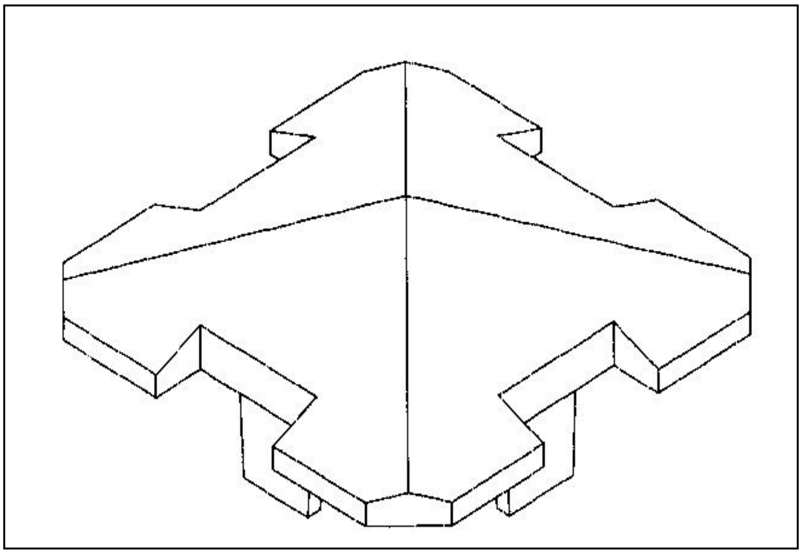

Figure 1.1 The design of column end cap (CECap) as the end product of Rice Husk-HDPE (RHPE) composite based component.

The study consists of four stages: material development, material characterization, moulding conditions on the selected formulation and end-use performance. The development of the material involved the raw material identification and characterization up to the composite preparation. The objective in the material development stage was set to identify the processable material for injection moulding. In characterizing the material, an objective is set to obtain the material that has the best impact properties. The selected material was then proceeded to produce the CECap part via injection moulding. When producing the part, a few moulding variables has been considered to achieve the perfect CECap product.

Research on injection moulded LTCs were reported by a few researchers outside Malaysia. Abu-Sharkh and Hamid (2003) have studied on the date palm fibre-polypropylene composites; Yang *et al.* (2004 and 2005) concentrated on rice husk flour filled polypropylene composites; Panthapulakkal *et al.* (2005) and Sain (2005) moulded wheat straw fibre filled polypropylene composites; while Stark and Matuana (2002, 2003 and 2004), Keener *et al.* (2004) and Clemons and Ibach (2004) were working on wood flour filled HDPE composites. Their product samples however were moulded into the standard shape of testing such as tensile, Izod or Charpy impact and flexural test.

Based from some local researchers, Premalal *et al.* (2002) for example has studied on rice husk powder filled polypropylene composites while Rozman *et al.* (2000, 2001, 2003a, 2003b and 2004) focused on the material testing of many other lignocellulosic composite types such as coconut fibre, oil palm empty fruit bunch (EFB), rice husk and oil palm frond fibre. The composite's samples however were prepared via compression moulding (hot-pressed technique) and cut into testing shapes.

Since there is limited research on injection moulded LTCs in Malaysia, a study on the injection moulding process to produce the LTCs is necessary to bridge the gap of technology with other advanced countries. Data obtained from the study can be used as a guideline by local manufacturer in producing the rice husk-HDPE composite product or other lignocellulosic composite material which is similar to the RHPE composite properties.

1.2 Problems Statement

There are very limited reports about the production of LTC using injection moulding technique. Although some of the overseas manufacturers have established their work in this area but only a few of them used rice husk as filler since this type of cellulose is reported as regional.

Especially in Malaysia, this technology is quite new and not yet established. As we know, there is none of LTC manufacturer in Malaysia involve in injection moulding process. Most of them concentrate in extrusion process and currently produce LTC profiles as their main product (known as wood-plastic composite lumber). Extrusion process is preferred because it is much easier and promises a well distribution of filler compared to injection moulding process.

Injection moulding process needs a lot of considerations especially in the composite formulations and processing parameters. This method of processing has the advantages for moulding a more complicated shape of product. Composite formulation is then adjusted to meet the processing requirements.

In order to commercialize rice husk-HDPE (RHPE) composite using injection moulding process, a study of the processing parameter in injection moulding has probably guide our local manufacturer in their production. This study was carried out to develop an optimal formulation and processing condition for rice husk based HDPE component using injection moulding process instead of typical extrusion process. Some basic concept assist very much at the beginning and this was followed by some modifications of work.

List of problems statement:

i) Which size of rice husk filler is suitable for the RHPE composite manufacturing? Is it suitable for injection moulding process?

ii) What is the optimum composition of rice husk as filler for the HDPE composite?

iii) In what condition should the injection moulding be operated to produce the column end cap component using the selected formulation?

iv) What is the effect of weathering and water absorption on the aesthetic and mechanical properties of rice husk-HDPE composite?

1.3 Objectives

This study aimed to develop an optimal formulation and processing condition for rice husk based HDPE component using injection moulding process instead of typical extrusion process for construction component such as column end cap. The main objective was further divided into:

i. To identify the appropriate size of rice husk suitable as a filler in HDPE.

ii. To determine the optimum composition of rice husk to be used for injection moulding process.

iii. To investigate the optimum injection moulding process condition for the column end cap component production.

iv. To study the effect of weathering and water absorption degradation on the aesthetic and mechanical properties of rice husk-HDPE composite.

1.4 Scopes

The scopes of this research include:

- Identification of suitable rice husk type for moulding from four sizes of rice husk that was classified as A, B, C and D.

- Selection of the best composition of rice husk that can be moulded with good impact strength. The percentage was varied from 30, 40 and 50 % rice husk.

- The processing parameters optimization such as the barrel temperature, cycle time and cooling time for easy flow, material processability and product homogeneity in the injection moulding. The parameters were optimized by Taguchi method.

- Weathering and water absorption tests were conducted on the rice husk-HDPE composite. Samples after these tests were analyzed on impact strength, morphology and colour changes.