MICROCELLULAR STRUCTURES OF HIGH DENSITY POLYETHYLENE/WOOD FIBER COMPOSITE FOAMS USING CHEMICAL FOAMING AGENT

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1. Introduction

Due to the limitation of the use of fossil fuel, renewable and low cost materials are gaining popularity. Bio-composites reinforced with wood fibers and mineral fillers attract great attention as alternative materials. Particularly, researches with regard to WPC (wood plastic composite) materials have been continuously increased within the last 20 years because of the advantageous characteristics of each constituent in composite materials[1].

The need for the WPCs has been increased due to effective application of limited natural resources and environmentally friendly characteristics. Because of the outdoor durability and low maintenance cost, WPCs are being widely used in various applications such as deck, fence, marina, sound-proof wall, furniture, and automotive parts[2].

Although the WPCs have been commercialized, their potential for use in many industrial applications has been limited because of their brittleness, low impact resistance, and high density compared to neat resins[1]. For overcoming these limitations of the WPCs, researchers have tried to adopt foamed WPCs. The foamed WPCs have microcellular structures in their inner part. Microcellular foamed polymer is a new class of materials characterized by cell densities larger than 10^9 cells per cubic centimeter of un-foamed materials and cell sizes in the range from tens of μm to hundreds of μm. WPC foams having microcellular structures offer a reduction in materials usage and thus the production cost[3, 4]. They have improved specific mechanical strength, toughness, and thermal stability[4].

Foamed WPCs are manufactured using chemical foaming agent (CFA) or physical foaming agent (PFA). The CFA generates gas such as CO_2, N_2, and NH_3 by high thermal process while PFA does not generate additional gases. The CFAs are mixed with thermoplastic, reinforcing agents, and coupling agents for injection molding or extrusion. However, the PFA needs additional equipments for injecting the gases into the machines. Therefore, use of CFAs is relatively simple to examine the effect of foaming on the physical properties of formed composites.

The CFAs used in the WPCs foam are categorized into two basic types: endothermic and exothermic. Endothermic CFAs absorbs heat while exothermic agent releases heat during decomposition. These behaviors of the CFAs affect on morphology, distribution, and size of cells generated by the agents. Our present works aim to develop formed WPCs through injection molding method. We investigated effects of CFA on cell morphology and physical properties of formed WPC.

2. Experimental

High density polyethylene (HDPE, ME9180) was used as base materials, and it was supplied from LG Chemical Ltd. Its melt flow index was 18g/10min at 190^{o}C and its density was 0.958 g/cm^3 at room temperature. Lignocel® C120 (natural wood fiber from JRS, Germany) was used, and its grain size and bulk density are 70μm-150μm and 100-135g/L, respectively. For achieving microcellular structure in WPC, exothermic foaming agent was used. Cellcom-AC series (CFA, size range from 5 to 18μm) were obtained from Kumyang Co. Ltd. The size information of the two types of CFA used in this study is described in Table 1. WPC foams were prepared by an injection molder (Boy 12 M, Dr. Boy GmbH & Co. KG, Germany). Injection foaming was performed at 205-210 °C because decomposition temperature of CFAs were 205 °C.

Table 1 Size ranges of chemical foaming agents used in this study.

CFAs	Size ranges(μm)
AC1000	16~18
AC9000	5~6.2

3. Results and Discussion

3.1 Density & void fraction

Fig. 1 shows the reduction of density with increasing CFA content in WPCs because amount of liberated gas is proportional to CFA content. Density of foamed WPC increases with wood fiber content.

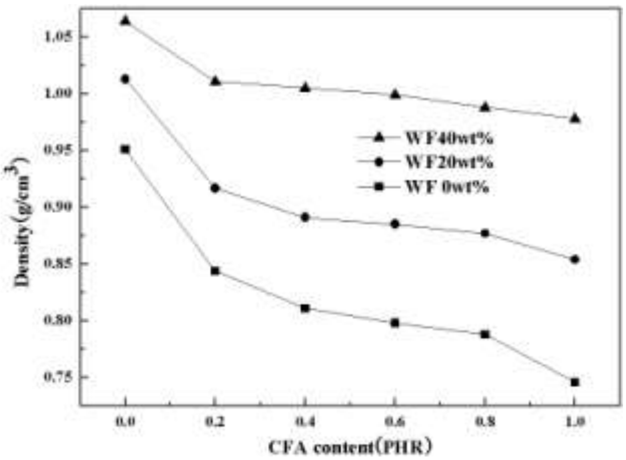

Fig. 1. Density of WPC foams for various CFA contents at different wood fiber contents.

Fig. 2 shows the increase of void fraction with increasing CFA content at all wood fiber contents in our experimental ranges. It is commonly believed that high amount of released gas generate many cells in WPCs. Also, the void fraction was reduced with increasing wood fiber content. HDPE resin in the WPCs is a gas bubble growing site. The decrease of the resin content could lead to reduction of cell amount in the composites.
Fig. 3 shows particle size effect of CFAs on foam density for various CFA contents at fixed wood fiber content (20wt%). The CFA having small particle size increases density of foamed WPC in experimental range.

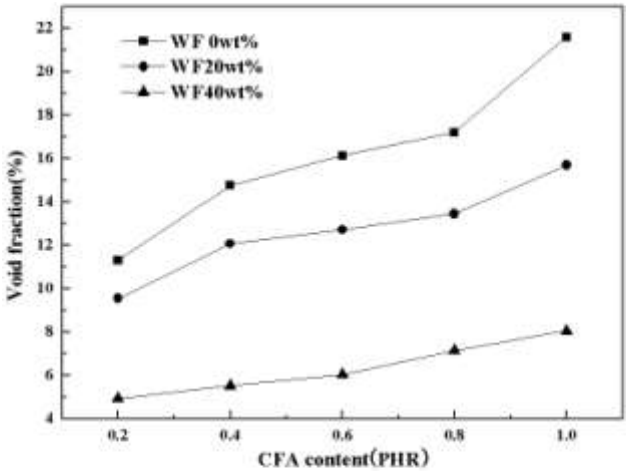

Fig. 2. Void fraction of WPC foams for various CFA contents at different wood fiber contents.

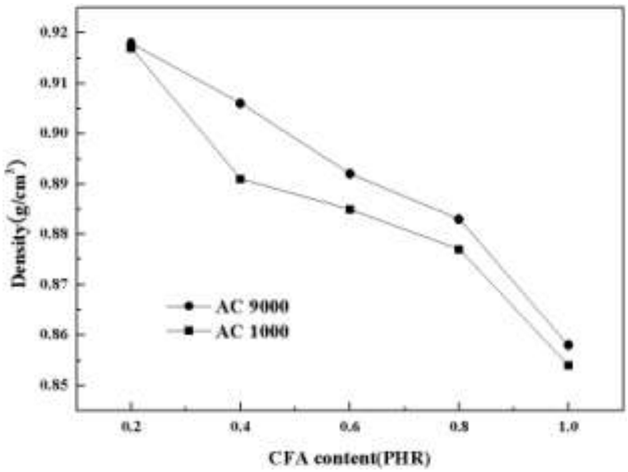

Fig. 3. Density of foamed WPC as a function of CFA content varying particle sizes of foaming agents.

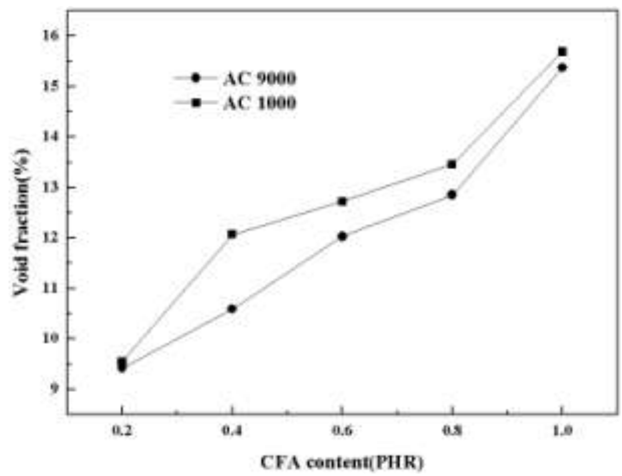

Fig. 4. Void fraction of foamed WPC as a function of CFA content varying particle sizes of foaming agents.

Fig. 4 describes the effect of CFA particle size on void fraction for various CFA contents at 20wt% wood fiber content. The CFA (AC9000) having small particle size decreases void fraction of foamed WPC in experimental range. The results (Fig. 3 and 4) might be that large particle liberates more amount of gas than small particle.

3.2 Flexural strength

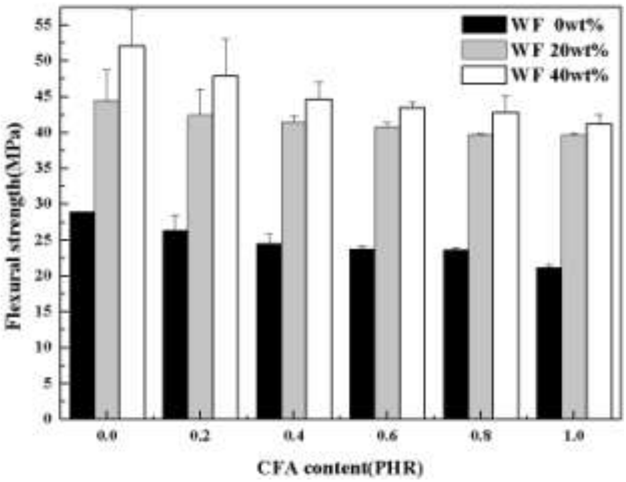

Fig. 5. Flexural strengths of unfoamed and foamed WPCs with various CFA content at various wood fiber content.

Flexural strengths of unfoamed and foamed WPCs with various CFA content at various wood fiber content are shown in Fig. 5. The void content in WPCs is a crucial role in their strength. Void leads to reduction of mechanical properties of WPCs. As shown in the Fig.2, the void content increases with CFA content. Therefore, flexural strength of foamed WPCs decreases with increasing CFA contents.

Fig. 6 shows effects of the CFA particle size on flexural strength of WPCs. The flexural strength of WPC added large CFA particle (AC1000) decreases in comparison to that of small one. This result could be explained by void content as described in Fig. 5.

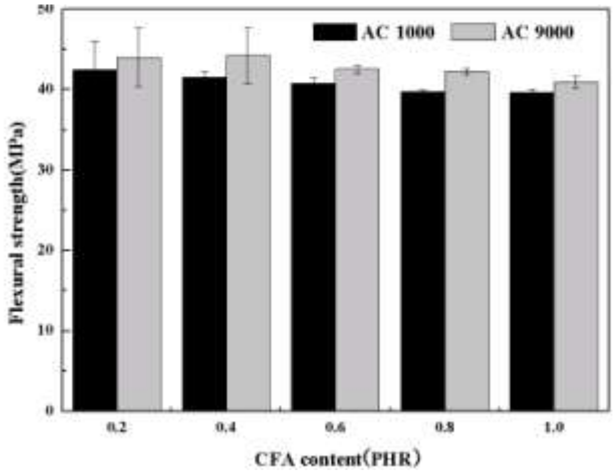

Fig. 6. Effects of CFA particle size on flexural strength of WPCs.

3.3 Wax effects on physical properties

Table 2 Wax effects on density and void fraction at 20wt% wood fiber content.

Wax(wt%)	Density (g/cm^3)	Void Fraction (%)
0	0.877	13.46
2	0.874	13.72

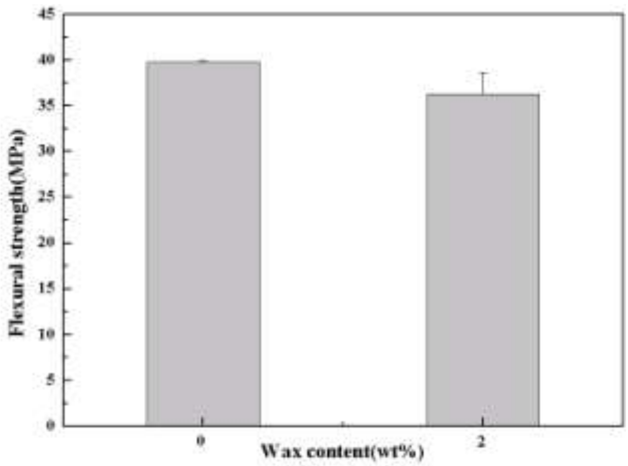

Fig. 7. Effect of the wax on flexural strength at 20wt% wood fiber content.

Table 2 shows the effects of wax on density of void fraction of foamed WPCs. The wax decreases density and increases void fraction of foamed composite. It could be possibly explained by change of viscosity. A melt viscosity of the matrix increases with wood fiber content, generating high resistance to cell growth in the foaming process[5]. It is well known that the wax having low molecular weight decreases the polymer viscosity. Therefore, the wax might decrease resistance to cell growth.

Fig. 7 shows effect of wax on flexural strength of foamed WPC. The addition of wax decreases the strength of the composites because of introducing low molecular weight in the polymer matrix.

3.4 Morphology of the foamed WPCs

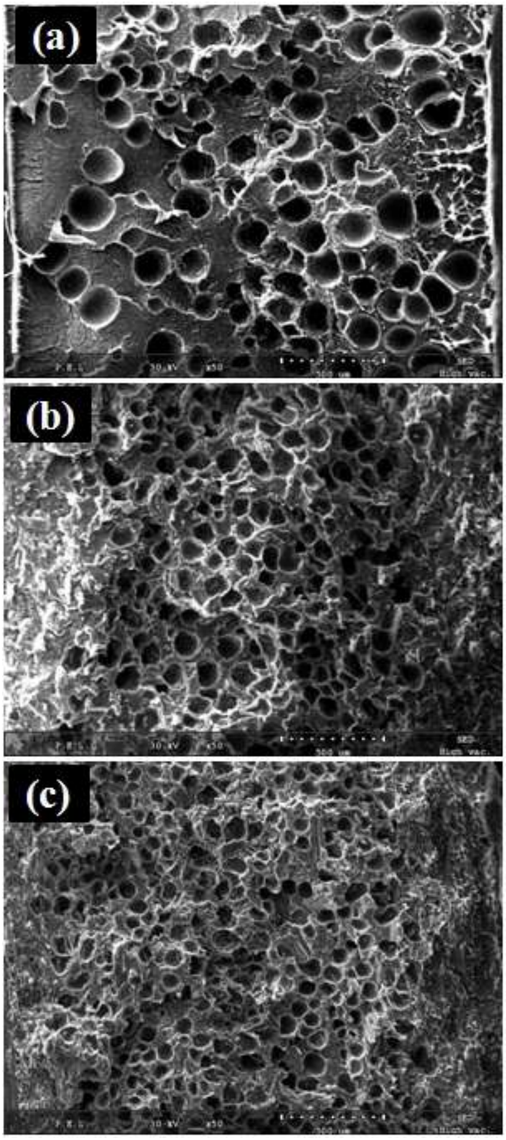

Fig. 8. SEM photographs of microcellular structure of foamed composites with various wood fiber contents: (a) 0wt%, (b) 20wt%, and (c) 40wt% (at CFA content 0.6PHR, all scale bars mean 500μm).

Cell size decreased as increasing wood fiber content as shown in Fig. 8. It could be also explained by change of viscosity, as already mentioned in Table 2.

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