PREPARATION OF POLYMER COMPOSITES BASED ON UNSATURATED POLYESTER REINFORCED BY NATURAL FIBER AND CELLULOSE MICROFIBER FROM LUNG WASTE IN NGHE AN

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ABSTRACT

Unsaturated polyester composites reinforced by glass fiber and by hybrid reinforcement glass fiber - lung fiber with cellulose microfiber (MFC) were prepared and investigated. Tensile and flexural strengths of material reached the highest value at polymer composite with 48 %w glass fiber mat and 0.3 %w MFC (208.33 MPa and 243.6 0 MPa), while the highest impact strength reached 212.48 kJ/m^2 at composite containing 48 %w glass fiber but 0.5 %w MFC. Especially, with 0.3 %w MFC, the tensile fatigue cycle to failure of composite processed by vacuum bag remarkably increased, 140.28 % at composite with 48 %w glass fiber and 265.63 % at hybrid composite reinforced by glass fiber/lung fiber, compared to samples without MFC.

Keywords: cellulose microfiber, lung fiber, glass fiber, polymer composite, unsaturated polyester.

1. INTRODUCTION

Unsaturated polyester (UPE) resins are widely used in preparation of polymer composite. In Vietnam, some studies have been carried out on improvement of the physical properties of UPE by silicafume [1], chopped aramid fibers [2], by fly ash [3]. Besides, polymer composites reinforced with natural fibers, especially, with cellulose microfiber (MFC) has been interested by many researchers due to their salient advantages compared to traditional reinforcement fibers (carbon, glass fibers…), such as, high mechanical strength, low density, biodegradability, natural renewable resources [4]. Takagaki et al. [5] used 0.1 %w and 0.3 %w MFC to improve the fatigue strength and impact properties of MFC-CF-Epoxy. In addition, MFC also improved thermal and flexural strength properties of polymer composite based on epoxy resins and polylactic acid [6, 7] and biodegradability of nanocomposite [8]. However, studies on using the natural fibrils in combination with MFC to reinforce polymer composite based on UPE virtually are at the beginning and in the first step to attract the attention of researchers.

2. MATERIALS AND METHODS

2.1. Materials

Unsaturated polyester resin 268 BQTN (Singapore), glass fiber mat (density: 360 g/m^2), curing agent Trigonox V388 (Methyl ethyl ketone peroxide) of Akzol Nobel (China).

Lung fibers mat (density: 190 g/m^2) which the average diameter was about 150 - 200 µm, was prepared by the raking method then treating alkali at Research Center for Polymer Materials, Hanoi University of Science and Technology.

The pulp with Kappa index 21 from lung foil waste that preparation by sulfate pulping method at Research Institute of Pulp and Paper industry.

2.2. Preparation and dispersion of MFC

Mixture UPE/pulp was grinded by Ball Mill of Planetary Type, Model: ND2L (China). After making smooth by electric blender, the pulp mixed into UPE with 3 %w. The number of mill balls were 40 mill balls Ø10 mm and 150 mill balls Ø 6 mm.

2.3. Preparation of polymer composite

Polymer composites were prepared at Research Center for Polymer Materials, Hanoi University of Science and Technology. In order to investigate the influence of processing method and technological composition on physical properties of composite, 4 samples were prepared:

Group A: UPE without MFC (sample A_0) and UPE with MFC in the weight ratio MFC/PEKN as 0.3 % (sample A_1), 0.5 % (sample A_2), 0.7 % (sample A_3) and 1 % (sample A_4), cured by V388 following ratio V388/PEKN as 0.6%w. Mix well and then pour the mixture into mould for curing.

Group B: Prepare composite reinforced by 48 %w glass fiber mat without MFC (sample B_0) and with MFC following the weight ratios: 0.3 % (sample B_1), 0.5% (sample B_2), 0.7 % (sample B_3) và 1 % (sample B_4), based on the weight of UPE. Composite material samples with 8 layers of glass fiber mat were preared by hand-lay up method.

Group C: Prepare copmposites in same composition as group B, but use the vacuum bag with vacuum of 0.1- 0.15 at. as processing method.

Group D: Prepare the hybrid UPE/ glass fiber mat/ lung fiber mat in coat-shell structure, with 4 layers of lung fiber mat as the coat and 2 layer of glass fiber as the shell, the ratio glass fiber-lung fiber/UPE was 48 %w, V388/UPE as 0.6 %, the content of MFC in the samples were 0 % (sample D_0), 0.3 % (sample D_1), 0.5% (sample D_2), 0.7 % (sample D_3) and 1% (sample D_4).

The curing process of polymer composite samples was carried out at room temperature for 12 hours, after that they were removed from mould and additionally heated at 70^oC for 4 hours. Physical properties of composite samples were then tested.

2.4. Testing methods

The surface morphology of destroyed samples was studied on the SEM- Scanning Electron Microscopy Jeol 6360 LV (Japan) at Advanced Institute for Science and Technology, Hanoi University of Science and Technology. Samples with the dimension 2mmx2mm were coated with an Ag layer and were then studied in vacuum room of equipment.

Tensile strength and flexural strength were tested following the standars ISO 527-1993 and ISO 178-1993 (E), on an INSTRON 2 - 100KN (USA), with the speed of 2 mm/min, temperature of 25 ˚C, humidity of 70 - 75 %. Impact strength IZOD test followed the ISO 180 & ASTM D256, on a Tinius Olsen (USA), at 25 ^{0}C. Fatigue properties were tested on equipment MPS 810 (Material Test System 810- USA), following standar ASTM D3479-96 (2007), the working force for fatigue cycle test was 70 % of tension-to-break force of the samples, f = 2Hz equivalent to 120 rpm, vibration amplitude of the force was 2 times of working force. These physical properties were studied at the Research Center for Polymer Materials, Hanoi University Science and Technology.

3. RESULTS AND DISCUSSION

3.1. Influence of MFC and processing method on tensile strength

The tensile strengths of samples in Table 1 showed that with the increase of MFC content from 0.3% to 1% the, tensile strength of samples in group A decreased from 19.57 % to 78.19 %, and that of samples in group B decreased from 9.15 % to 36.14 %, compared to samples without MFC. That might be, that the MFC might cause defects in the sample, leading to decrease of the tensile strength. In groups C and D, sample C_1 và D_1 possessed highest tensile strength. The tensile strength of samples C_1 and C_2 were higher than that of C_0 12.21 % and 4.56 %, and that of D_1 and D_2 higher 5.35% and 3.83% compared with D_0. Samples C_3 and C_4, D_3 and D_4 also possessed decreasing tensile strength with increasing MFC content.

Table 1. Tensile strength (MPa) of polymer composite.

MFC content	Group A		Group B		Group C		Group D	
0%	A_0	43.33	B_0	165.82	C_0	185.66	D_0	82.30
0.3%	A_1	34.85	B_1	150.65	**C_1**	**208.33**	**D_1**	**86.70**
0.5%	A_2	25.89	B_2	137.41	C_2	194.12	D_2	85.45
0.7%	A_3	13.87	B_3	126.28	C_3	168.51	D_3	64.89
1%	A_4	9.45	B_4	105.89	C_4	159.33	D_4	57.65

In comparision of samples of group C with group B it can be seen that with the same MFC content, the tensile strength in group C were much higher than that in group B. Polymer composite reinforced by glass fiber mat containing 0.3 % MFC, processed by vacuum bag, reached the highest tensile strength (208.33 MPa). The presence of small MFC content and utilisation of vacuum bag in processing lead to better quality of composite and show higher effect in processing of material, compared to hand-lay up method, due to higher pressure on the vacuum bag containing sample.

3.2. Influence of MFC and processing method on flexural strength

The result of flexural strength test listed in Table 2 showed that with increasing MFC content, the flexural strength of samples in group A decreased from 26.52 to 78.48. However flexural strength in groups B, C and D slightly incresed with MFC content of 0.3 %, and then decreased with higher MFC content. It can be seen that with the MFC content of 0.3 %, samples

B_1, C_1 and D_1 showed the highest flexural strength in group B,C,D, respectively. With the same MFC content, group C possessed better flexural strength: strength of C_0 was 18.33 % higher than B_0; of C_1 16.76 % higher than B_1, of C_2 23.89 % higher than B_2, of C_3 15.23% higher than B_3, and that of C_4 was 18.46 % higher than that of D_4.

Table 2. Flexural strength (MPa) of polymer composite.

MFC content	Group A		Group B		Group C		Group D	
0%	A_0	70.90	B_0	192.40	C_0	227.67	D_0	132.60
0.3%	A_1	52.10	**B_1**	**208.63**	**C_1**	**243.60**	**D_1**	**132.70**
0.5%	A_2	49.54	B_2	186.74	C_2	231.36	D_2	128.52
0.7%	A_3	21.30	B_3	162.78	C_3	187.57	D_3	124.71
1%	A_4	15.26	B_4	149.34	C_4	176.91	D_4	101.32

The result showed that the processing method vacuum bag can cause material with higher flexural strength than hand-lay up method. The composite material reinforced by glass fiber containing 0.3 % MFC and processed by vacuum bag reached highest flexural strength (243.60 MPa).

3.3. Influence of MFC and processing method on impact strength

The result of impact test listed in Table 3 showed, the presence of a small MFC content from 0.3 to 0.5 % leaded to improvement of impact strength of all sample groups. It can be seen that impact strength of sample A_1 was 66.84 % higher and of A_2 was 70.82 % higher than that of A_0. Impact strength of B_1 and B_2 were 18.04 % and 27.34% higher than that of B_0 18.04 %. Similarly, C_1 and C_2 possessed better impact strength compared to C_0 (21.34 % and 24.39 %), at D_1 and D_2 also 14.4 % and 11.36 % higher compared to D_0. It might be, with small dimension, MFC can adsorb better impact force, change the direction of micro fracture, reducing development speed of fracture inside sample, leading to a delay of material destroy. However, at the MFC content of 0.7 % or more, the impact strength slighly decreased at all samples.

Table 3. Impact strength (kJ/m^2) of polymer composite.

MFC content	Group A		Group B		Group C		Group D	
0%	A_0	9.80	B_0	158.28	C_0	170.82	D_0	31.25
0.3%	A_1	16.35	B_1	186.84	C_1	207.28	**D_1**	**35.75**
0.5%	A_2	16.74	**B_2**	**201.55**	**C_2**	**212.48**	D_2	34.80
0.7%	A_3	15.40	B_3	177.23	C_3	197.56	D_3	33.10
1%	A_4	13.20	B_4	155.38	C_4	187.20	D_4	32.40

From Table 3 it can also be seen that at the same MFC content, all the samples of group C possessed higher impact strength than that of group B. So, polymer composite reinforced by glass fiber mat, processed by vacuuum bag have had better impact strength than processed by hand-lay up method.

3.4. Influence of MFC and processing methods on fatigue property

The results of tensile, flexural and impact tests showed that the MFC content of 0.3 % was the optimal content for preparation of polymer composite and it would be used to investigate fatigue property. The presence of MFC strongly improved the fatigue property of material. At 0.3 % MFC, sample D_1 was destroyed after 23826 cycles compared to 10166 cycles of D_0 (increased 265.63 %), C_1 at 34312 cycles compared to 14248 of C_0 (increased 140.82 %); and sample B_1 at 23826 cycles compared to 10166 cycles of B_0 (increased 134.37 %). For polymer composite with glass fiber mat, pocessing by vacuum bag also gave much better fatigue property than by hand-lay up method. For example, without MFC fatigue property of C_0 increased 40.15% compared to B_0 (14248 cycles compared with 10166 cycles); with 0.3 % MFC sample C_1 was destroyed at 34312 cycles compared to 23826 cycles of B_1 (increased 44.01 %).

3.5. Study on surface morphology

SEM images of polymer composite have been given in Figure 1. It can be seen that without MFC polymner composite surface showed a brittle fracture with big glat surface and a lot of cracking lines (Fig. 1a and Fig. 1c).

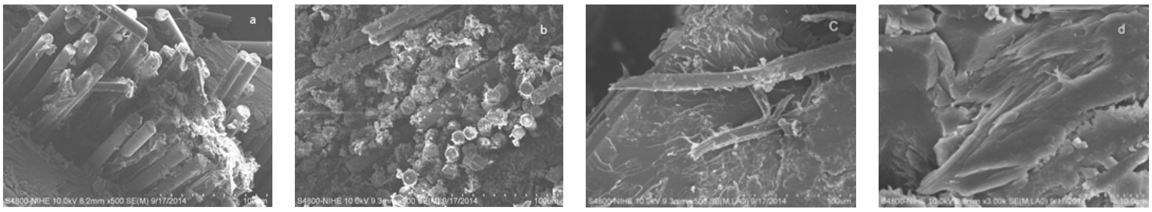

Figure 1. SEM images of polymer composite without MFC (1a) and with 0.3% MFC (1b); polymer composite reinforced by glass fiber mat- lung fiber mat without MFC (1c) and with 0.3% MFC (1d).

In polymer composite containing MFC (Fig.1b and Fig.1d), the matrix resin showed the fracture with small pieces, forming a rough surface. That means that MFC played an important role in protection of polymer composite, slowing down the development of the crack and rupture in composite, and therefore can improve physical properties of material. Processing by vacuum bag with low pressure in the bag may cause a better wettability of the resin on the reinforcement and MFC surface, leading to better quality of material

4. CONCLUSIONS

The study on preparation of polymer composite based on UPE, reinforced by glass fiber-lung fiber and MFC, and on its physical properties showed, that the vacuum bag is an effective processing method giving material with higher physical properties compared to hand-lay up method. By addition of 0.3 %w and 0.5 %w MFC, polymer composite UPE/glass fiber mat and hybrid composite UPE/glass fiber mat-lung fiber mat processed by vacuum bag possessed higher tensile, flexural and impact strength. Especially, the presence of MFC can remarkably improve fatigue property of material, 140.82 % for composite UPE/glass fiber and 265% for hybrid composite, in comparision with material without MFC.

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TÓM TẮT

CHẾ TẠO VẬT LIỆU POLYME COMPOZIT TRÊN CƠ SỞ NHỰA POLYESTE KHÔNG NO GIA CƯỜNG BẰNG SỢI THỰC VẬT VÀ VI SỢI XENLULOZƠ TỪ PHẾ THẢI CỦA CÂY LÙNG Ở NGHỆ AN

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Vật liệu polyme compozit trên cơ sở nhựa polyeste không no (PEKN) gia cường bằng mat thủy tinh và compozit lai tạo mat thủy tinh/mat sợi lùng có bổ sung vi sợi xenlulozơ (MFC) đã được chế tạo và khảo sát một số tính chất cơ lý. Polyme compozit có độ bền kéo đứt và độ bền uốn đạt giá đạt giá trị lớn nhất lần lượt là 208,33 MPa và 243,60 MPa ở mẫu vật liệu gia cường bằng 48 % mat thủy tinh và 0,3 % MFC (về khối lượng), còn mẫu vật liệu gia cường bằng 48 % mat thủy tinh và 0,5 % MFC (về khối lượng) có độ bền va đập lớn nhất là 212,48 kJ/m^2. Đặc biệt, độ bền mỏi của polyme compozit gia cường 48 % mat thủy tinh và 0,3 % MFC được gia công bằng phương pháp túi hút chân không tăng 140,28 %, còn polyme compozit lai tạo mat thuy tinh-mat sợi lùng và MFC tăng 265,63 % so với mẫu vật liệu không có MFC.

Từ khóa: vi sợi xenlulozơ (MFC), sợi lùng, sợi thủy tinh, polyme compozit, polyeste không no.