ULTRAVIOLET RADIATION CURED BIO-FIBRE COMPOSITES FROM OIL PALM EMPTY FRUIT BUNCH

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Abstract

In this study, development of ultra-violet (UV) cured biofibre composites is reported. The composites were based on the pulp made from empty fruit bunch (EFB) as the reinforcing agent and unsaturated polyester as the matrix. The EFB fibres were treated with different concentrations of sodium hydroxide (NaOH) solutions. The results showed that the Kappa number of the EFB decreased as the NaOH concentration was increased. The composites were produced from EFB fibres, which were treated with 22% and 28% NaOH solutions. The flexural, tensile and impact strength of the composites made from 22% NaOH treated EFB showed an increasing trend as the % of EFB was increased. However, those with 28% NaOH treated EFB decreased as the % of EFB was increased. Generally, the results showed that composites with EFB fibres treated with 22% NaOH displayed higher flexural, tensile and impact strength. However, no significant difference was observed for both types of composite with respect to flexural modulus. The study revealed the influence of two important factors, (a) the decrease of the light absorptivity (as a result of the removal of lignin) (b) the degradation of fibre strength as a result of higher concentration of NaOH treatment.

Introduction

The thermoset fibre reinforced polymer matrix composites are currently produced from unsaturated polyester resins by thermally induced initiators. Examples are polyester pre-pregs, sheet moulding compounds, bulk-moulding compounds etc [1]. The production of these composites involves use of high temperatures and requires expensive moulds and hydraulic presses. Room temperature curing of such systems takes a long time.

Ultra-violet (UV) radiation are widely used in Malaysia in surface coatings especially in wood industry [2] and followed by printing, electronic and adhesive industry [3]. In recent times photo-curing process has been adopted for making composites that may prove superior to the thermal curing systems. This process employs ultraviolet radiation to cure the composites. The success of the photo-fabrication of polymer matrix composites by the use of UV radiation stimulated our interest to apply the radiation curing technology for the production of biofibre-composites and been a subject of study in our laboratory and a patent for the process is being filed on this [4].

Literature Review

The use of natural fibre reinforcement in synthetic polymer bonded composites has gained significant importance in recent times [5]. Natural fibre biomass can be renewed in perpetuity and hence can be used exclusively or in part in fibre reinforced composites. Biofibres can replace glass and other high cost fibres to make composites, which are considerably cheaper, less abrasive so that the tools for moulding will not be damaged. Oil Palm industry in Malaysia generated large quantity of biomass. Recent investigations show various products from oil palm tree produce such as oil palm component-plastic composite, oil palm component-rubber composite, sheet moulding compound, composites, pulp and paper [6]. Besides strong economic incentive, natural fibers in composites have lower in specific gravity, higher specific tensile strength, biodegradable, and less energy intensive to process, so they are well suited to these type of technologies [7]. The UV curable systems are well known in the field of surface coating and have distinct advantages of being solvent free, environmentally friendly and energy saving [8]. The entire process of curing occurs at room temperature and hence does not require expensive high temperature equipment to cause the cure [9]. Further there is no fire hazard. In view of the above advantages attempts have been made to make polymer matrix composites by employing UV radiation for affecting the cure.

Materials and Methods:

Materials

Unsaturated polyesters P9728 was purchased from Euro Chemo Pharma Sdn. Bhd.. Empty fruit bunch (EFB) was obtained from Sabutek Sdn. Bhd. Photointiator IRGACURE 1800 was supplied by Ciba Speciality (Singapore) Pte. Ltd.

Preparation of Composites.

EFB was pulped at four different concentrations of sodium hydroxide (NaOH); 8%, 15%, 22% and 28% under the following conditions: fiber:liqour ratio (1:10, vol/vol),
Temperature: 170°C and time of pulping: 2 hours. Fibers were formed into mat (20cm x 20cm) in a deckle box by the procedure reported earlier[4] and dried in oven at 80°C-100°C for 4 hours. After that, mats were pressed using hot press Gotech Testing Machine Inc model GT-7014-100 (2 minutes, 500 kg/cm^2, 100°C) and the thickness of the mats were controlled to ±1 mm. Three percent of photo-initiator IRGACURE 1800 was mixed with unsaturated polyester and poured onto EFB mat. The mat was impregnated with resin and the air bubbles if any were removed by means of a hand roller. After impregnation, mats were passed through 1ST UV machine for twenty passes at conveyor speed of 10m/min[10].

Testing.

The sheets produced into three type of test samples; i.e flexural, tensile and impact tests. Tensile tests were carried out on sample with dimension 10cm x 1.5cm x 0.1cm, using Universal Testing Machine model STM-10 at a crosshead speed of 1mm/min, according to ASTM D3039. Flexural tests were conducted according to ASTM D790, i.e a three – point bending, using Universal Testing machine model STM-10. The samples, with dimension 8cm x 1.2cm x 0.1cm were tested at a crosshead speed of 1.0 mm/min. The izod impact tests were carried out on unnotched samples with dimension 6.5cm x 1.2cm x 0.1cm, using an Impact Pendulum Tester (Zwick) model 5101 according to ASTM D252. A minimum of eight samples was tested in each case. Kappa number test were used to determine delignification process according to TAPPI 236 cm-85. Percentage of curing was determined through the Gel Content test and according to ASTM D2765.
The fractured surfaces of the composites from the tensile test were investigated with a Leica Cambridge S-360 Scanning Electron Microscope. All fracture surfaces were sputter coated with gold to avoid electrostatic charging and poor image resolution.

Results and Discussion:

1. Effect of Kappa number of the pulp on the degree of cure of the matrix of the composite

Fig. 1 shows how the degree of cure of the matrix material influenced by the kappa number of the pulp for different percentages of EFB pulp. Two important facts can be observed from this figure.

1. Influence of EFB pulp content in the composite
2. Influence of kappa number of the pulp

As the EFB pulp content in the composite increases, the gel content or the degree of cure of the matrix material decreases. This is due to the absorption of UV radiation by lignin present in the pulp. As the pulp content increases, the UV radiation is absorbed by the lignin present in the pulp and hence the depth of penetration decreases. The submerged layers of the composite do not receive sufficient light energy for cure. In other words, the submerged layers of the matrix material are in the shadow regions caused by the strong absorption of lignin present in the pulp.

Another interesting observation that can be made from the figure is that the gel content increases as the kappa number decreases. This is due to lesser quantities of lignin being present in the pulp and the light can penetrate more deeply into the matrix materials uninfluenced by unfavourable absorption of UV light by the top layers.

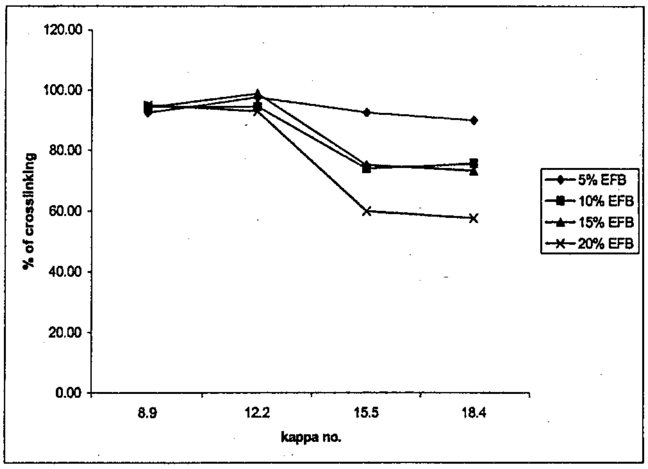

Fig. 1: Effect of Kappa number of the pulp on the degree of cure of the matrix of the composite

Effect of Sodium Hydroxide concentration on Kappa Number

From Fig. 2 it is obvious that the kappa number decreases as the percent of NaOH used in the pulping process increases. Hence use of higher concentration of NaOH for pulping is thus favourable for producing pulp with lesser amounts of lignin. This is a desirable condition for ensuring the complete cure of the matrix material in the composite. As reported in the previous paragraph this is true with respect to degree of cure. It should however be examined whether pulping under such high alkali concentrations is conducive to produce composites with mechanical strengths unimpaired. Hence, experiments were conducted to determine the effect of alkali concentration on flexural strength, flexural modulus, tensile strength, tensile modulus, and impact strength

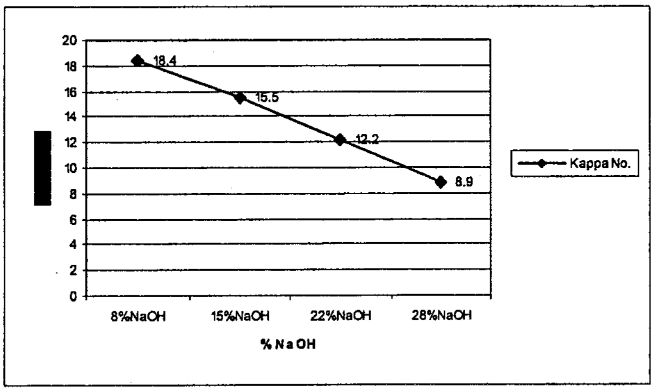

Fig. 2: Effect of Sodium Hydroxide concentration on Kappa Number

Effect of % NaOH in the pulp cooking liquor and EFB pulp percentage in composite on the flexural strength

Fig. 3 shows how the concentration of sodium hydroxide employed in pulping affects the flexural strength. The figure depicts the influence of percent of EFB pulp cooked with 22% NaOH and 28% NaOH on the flexural strength. In the case of EFB pulped with 22% NaOH the flexural strength increases up to above 56 MPa at 15% EFB and thereafter reduces to about 54 MPa at 20%. Although removal of lignin is conducive to a general increase in the light penetration and satisfactory cure, it is noticed that higher percent of fibre in the composite may still absorb light and prevent deeper penetration. It can further be noticed that pulp made with 28% NaOH produces composites with lesser flexural strength than the pulp made with 22% NaOH. It is evident that fibre damage occurs at higher alkali concentration, which could be the cause for reduced flexural strength.

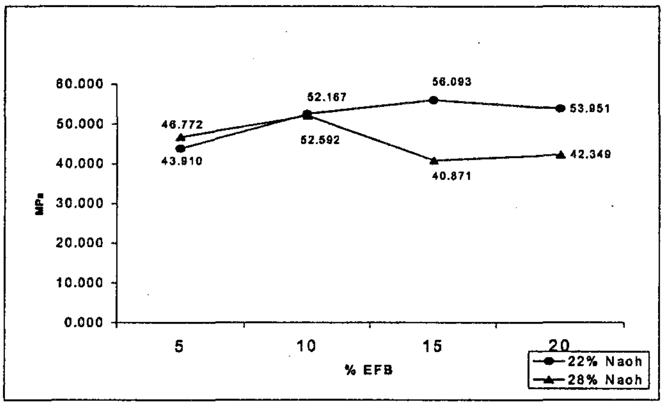

Fig. 3: Effect of percent of NaOH in the pulp cooking liquor and EFB pulp percentage in composite on the flexural strength

Effect of % NaOH in the pulp cooking liquor and EFB % in composite on the tensile strength

Fig. 5 gives the effect of percent of EFB pulp cooked under two different alkali concentrations in the cooking liquor on the tensile strength. It can be noticed that as the EFB fibre content increases the tensile strength increases. But the fibres cooked at 28% NaOH produced composites with lower tensile strength than the fibres cooked at 22% NaOH. This may be due to the loss in strength of fibres due to increased alkali concentrate.

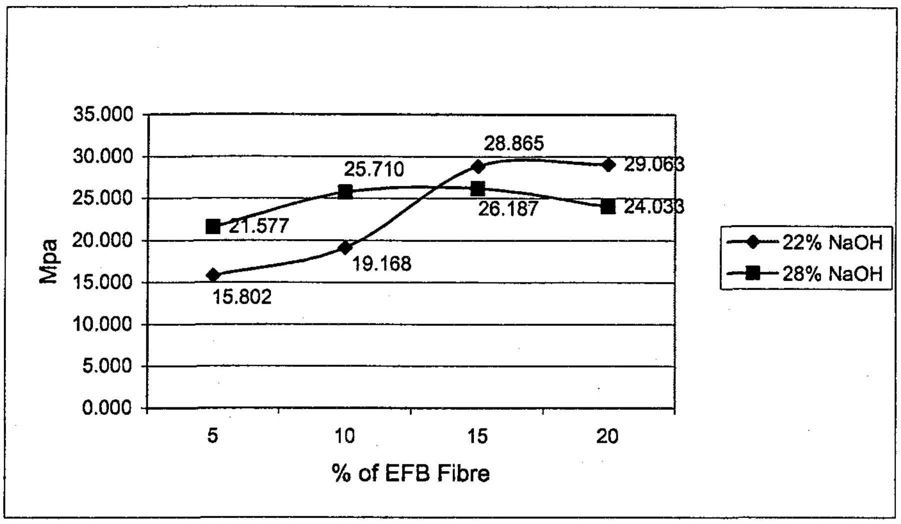

Fig. 5: Effect of % NaOH in the pulp cooking liquor and EFB % in composite on the tensile strength

Effect of % NaOH in the pulp cooking liquor and EFB % in composite on the impact strength

As the EFB% increases the impact strength increases up to 10% fibres and thereafter decrease. Pulp cooked in the liquor of 28% alkali concentration produces composites with lower impact strength than the pulp made at 22% alkali concentration. Light penetration as well as the fibre damage caused by increased alkali concentration in the pulping liquor appears to be the contributory factors in this case as well.

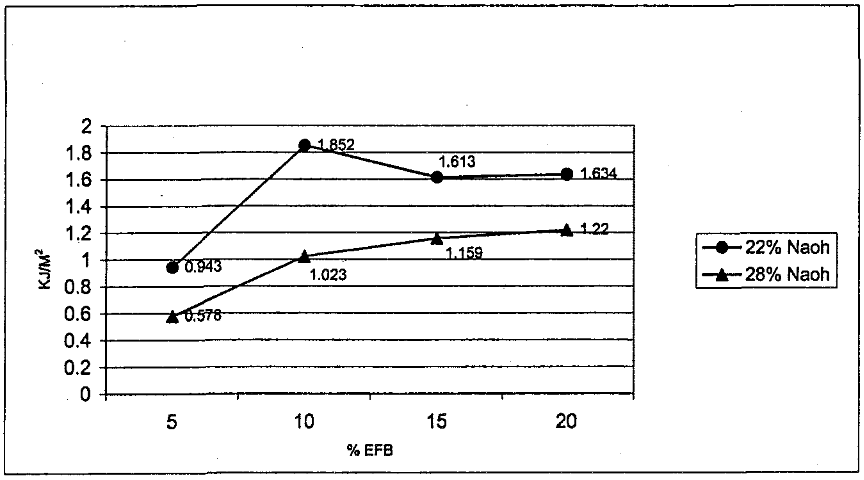

Fig. 6: Effect of % NaOH in the pulp cooking liquor and EFB % in composite on the impact strength

Conclusion:

The UV curable biofibre based polymer matrix composites can be produced by employing EFB pulp as the reinforcing fibre and unsaturated polyester resin as the polymer matrix. The degree of cure and the mechanical properties are related to the lignin content since lignin absorbs the UV light strongly and hence control the penetration depth and the degree of cure in the submerged layers of the composite. Although higher percentages of sodium hydroxide in the cooking liquor can produce pulp with low kappa numbers, which is desirable condition for promoting better penetration of light, there is a concurrent damage caused to the fibres due to higher alkali cooking.

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