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論　文　内　容　要　旨

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学位論文題目	STUDY ON MECHANICAL PERFORMANCE OF HYBRID GREEN COMPOSITES OF POLYLACTIC ACID REINFORCED BY KENAF, BAMBOO AND COIR FIBERS（ケナフ，竹，コイアによって強化されたポリ乳酸系ハイリッドグリーンコンポジットの機械的性能に関する研究）		

内容要旨Abstract

This study investigated the mechanical properties of unidirectional kenaf, bamboo and coir fiber-reinforced polylactic acid (PLA composites. A hand lay-up technique was used to prepare the composites with fiber weight content varying from 40 wt.% to 70 wt.%. The various composites were fabricated to investigate the effect of fibers' composition in monolithic green composites and hybrid green composites. These composites were named as green composites since they were made up from fully biodegradable materials. To investigate the performance of the composites, numerous tests were done. At first, fiber bundle tensile tests were conducted, followed by tensile, flexural and impact tests for monolithic and hybrid green composites to analyze their properties. In addition, two stacking sequences of low and high modulus fibers in the outer layers were compared to evaluate the composites' performances. Scanning electron microscopy was used to observe the fracture surface morphology.

The result of tensile strength on monolithic green composites was used to estimate the compatibility of fibers and PLA matrix. It was shown that at up to 70 wt.% fiber content, kenaf/PLA achieved approximately 290 MPa, and bamboo/PLA achieved approximately 210 MPa, producing higher strength than coir/PLA (55 MPa). Based on these results, with a higher content of kenaf and bamboo fibers, the strength would increase while a higher content of coir fibers does not contribute to the strength properties of the composites. On the other hand, coir fiber produced a higher elongation in the composites. Therefore, to optimize the strength properties in this hybrid, kenaf and bamboo fibers are the main factors that influence strength. In terms of adhesion between PLA matrix and fibers, bamboo was incompatible with PLA due to evident voids and fibers pull out from composites upon fracture. A further chemical modification is recommended for bamboo fibers.

According to the results of tests on three types of high modulus fibers in the outer layer of hybrid composites: KBCCBK/PLA, KCCK/PLA and BCCB/PLA, the tensile strength of KBCCBK/PLA composite achieved 187 MPa, approximately 20 and 78% higher than that of BCCB/PLA and KCCK/PLA, respectively. The Young's moduli of the three composites ranged from 6 to 7.5 GPa. High flexural strength was obtained in both KBCCBK/PLA (199 MPa) and BCCB/PLA (206 MPa) composites, approximately 16 and 20% higher than that of KCCK/PLA, respectively. However, KCCK/PLA composites showed the highest flexural modulus, approximately 70% higher than those of other combinations. Higher strain energy per unit volume required to break (toughness) was the characteristic of KBCCBK/PLA composites. It was found that the combination of high strength and stiffness of bamboo and kenaf fibers (outer layer) and high ductility of coir fiber improved tensile and flexural strengths compared to monolithic fiber green composites, particularly the coir fiber-reinforced PLA.

As high mechanical properties were obtained from using high modulus fibers in the outer layers, the effect of two symmetrical stacking designs of hybrid green composites were compared with high modulus fibers in the outer layers (KBC/PLA) and low modulus and high strain fibers in the outer layer (CBK/PLA). Tensile, flexural and impact tests were conducted to investigate their mechanical properties with total fiber content varying from 50 to 70 wt.%. Field emission scanning electron microscopy was used to observe the microstructural failures. The tensile strength of both composites had a similar trend and increased linearly up to 158 MPa. The tensile modulus was approximately 6 to 7 GPa. It showed that the stacking sequence with high modulus fibers in the outer layers (KBC/PLA) improved flexural strength, approximately 49% higher than that of CBK/PLA with low modulus fibers in the outer layers. In contrast, the impact strength of composites with low modulus fibers in the outer layers (CBK/PLA) was approximately 21% higher than that of its counterparts. It was also found that the stacking sequence had no significant effect on tensile strength, while affecting tensile strain, which was increased approximately 58% due to the low modulus and high strain in the outer layer. As a consequence of water absorption, both composites' stacking sequences had weight increase significantly with fiber content after 48 hours of submerging in water (50 °C) when the weight increased 26-34 % and 28-39% for KBC/PLA and CBK/PLA, respectively. It revealed that these composites are sensitive to water.

A further study was also done to investigate the damping loss factor of high modulus fiber in the outer layer (KBCCBK/PLA) composite to compare with those of selected synthetic composites. It was found that the loss factor of the hybrid green composites was considerably higher than those of synthetic composites due to the viscoelastic property of plant fibers.

In conclusion, hybrid green composites containing kenaf, bamboo, and coir fibers with bio-based polymer (PLA) were fabricated and their mechanical properties were assessed. The hybrid green composites provide fully eco-designed material, tailoring the inherited low mechanical properties of certain monolithic green composites.

Based on hybridization results:

1. The combination of three kinds of fibers which are kenaf, bamboo, and coir produced composites with better strain, toughness and damping loss factor properties.
2. High modulus fibers in the outer layer produced composites with better flexural properties.
3. Low modulus fibers in the outer layer produced composites with better impact strength.
4. The compatibility of kenaf-coir fibers and PLA matrix produced composites with high flexural modulus.
5. Stacking sequences had a small effect on tensile strength but had a major impact on flexural strength.
6. Hybrid green composites had higher damping loss factor than those of GFRP and CFRP.