Effect of Yarn Twist on Young's Modulus of Fully-green Composites Reinforced with Ramie Woven Fabrics

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INTRODUCTION

Today, development of materials technology using biomass is expected for creation of a sustainable society. Especially, the composite consisting of plant-based natural fibers and biodegradable resin, so-called the fully-green composites, is much expected for practical use. So far, we made textile green composites using biodegradable resin and plain woven ramie fabric and explored the deformation behavior [1]. Generally, it is said that deformation behavior of textile fabrics is dependent on the parameters such as fabric density, crimp angle of yarns, number of yarn twist and so on [2]. On the other hand, it is quite unknown if such dependencies are exhibited in a textile green composite in the same way. This study is thus to explore the effect of yarn twist on mechanical properties of textile green composites. The results showed that a new property inherent in the composites, different from textile fabrics, was found out especially in the change of Young's modulus.

EXPERIMENTAL

Folded ramie yarns (No.16, five twists) supplied from TOSCO Co. Ltd. was used as a reinforcing material. On the other hand, a film of cornstarch-based biodegradable resin (Cornpole film CPR-F3A) supplied from Nippon Cornstarch Co. was used as a matrix material.

Ramie fabric reinforcements with a plain weave structure were made using a manual weaving machine. Some folded ramie yarns were untwisted or further twisted, and used as wefts of the fabric to explore the effect of yarn twist. Ramie fabric reinforcement made of untwisted yarns is denoted as TLS, of which the number of yarn twist is decreased to 0.5/inch. The reinforcement made of twist yarns is denoted as THS, of which the numbers of yarn twist is increased to 6.5/inch. The reinforcement made of as-supplied yarn is denoted as HT2. Textile green composites were fabricated using hot-press machine (mini Test Press-10; Toyoseiki Seisakusho Co. Ltd.). One fabric was sandwiched between three resin films and pressed at 150°C and 2.33MPa for 10min. Subsequently, the composite was cooled down to room temperature under same pressure. Tensile specimens were cut off from the composite in 15 mm width. The thickness was about 2 mm. GFRP plates were attached using epoxy adhesive on the both ends of these materials. The gage length was 50mm. To explore the deformation behavior of fabric reinforcements, on the other hand, HT2, TLS and THS were cut off in 25 mm width, and 200 mm length. The gage length was 100mm.

Tensile test of the composites was carried out along their weft directions at room temperature at the crosshead speed of 0.5mm/min using an Instron-type testing machine (Autograph IS-5000; Shimadzu Co.). Tensile test of the fabric reinforcements was carried out at the crosshead speed of 150mm/min using a hydraulic testing machine (Servopulser EHF-EB10; Shimadzu Co.).

RESULTS AND DISCUSSION

The results were shown in Table 1. Values in the table are all averages. The results show that the Young's modulus and fracture strain were slightly reduced by decreasing the number of twist to 0.5/inch. On the other hand, the Young's modulus increased greatly and facture strain decreased by increasing the number of twist to 6.5/inch. On the other hand, tensile strengths of these composites are almost the same. A typical load-strain diagrams of TLS, HT2 and THS are shown in Fig.1. In the figure only initial behavior of the diagrams is shown and the load is normalized by dividing it by the number of longitudinal yarns. Initial slope of THS is less than that of others. Consequently, stiffness and tensile load decreased with increasing the number of twist. This behavior is quite opposite to that of textile green composite mentioned above. Difference between the fabric reinforcement and composite may be related to the degree of yarn deformation at portions between crimps. In general, yarns between crimps in a textile fabric extend largely as compared to yarns at crimps. Therefore, more numbers of twists deform the fabric more largely. However yarns' behavior in a textile fabric embedded in a matrix is related to deformations at crimps as well as at portions between crimps, because of load transfer mechanism of matrix. As the deformation at crimps is decided by stiffness along the radius of yarns, such as transverse modulus of elasticity, the increase in the transverse stiffness caused by further twisting restricts reduction in thickness, and results in hardening the composites. On the other hand, the decrease in the transverse stiffness of the yarn deforms the crimp portions. Thus, it is considered that such mechanism inherent in textile composites led to increase in Young's modulus of THS.

Table 1: Tensile properties of composites

Fabric reinforcement	Number of samples	Number of yarn twist (/inch)	Young's modulus (GPa)	Tensile strength (MPa)	Fracture strain (%)
TLS	6	0.5	3.22	75.2	4.11
HT2	4	3.5	3.91	74.8	4.28
THS	5	6.5	6.01	75.0	2.83

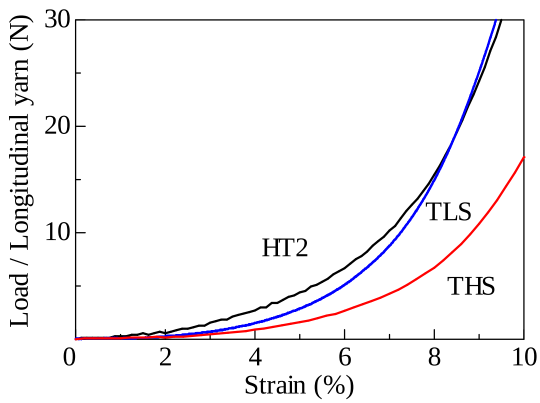

Fig. 1: Typical normalized load-strain diagrams of fabric reinforcement

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