Evaluation of residual strength after creep loading of a ramie staple fiber / PP green composite

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1. Introduction

Today, as is well-known, the construction of a recycling-oriented society is under way on a global scale. Thus, researches on green composites with a low environmental burden are actively carried out in the field of composite materials. Glass fiber reinforced plastics (GFRP) [1], have been used widely because of their excellent mechanical properties, but they are non-biodegradable and difficult to be disposed, resulting in a heavy burden to the environment. Although recycling research of GFRP is progressing, research and technology development that replaces the reinforcing material with biomass has gained interest, particularly studies and technology development in composite material using cellulose natural fibers [2] and cellulose nanofibers [3].

However, there are very few reports on durability of green composites. Hence, in this study, we used ramie staple fiber reinforced polypropylene composite materials and investigated the change of mechanical properties after creep loading.

2. Experimental

2.1 Test Materials and Molding Method

In this study, ramie fibers (made by Teikoku Fibers Co. Ltd.) with 10 mm length were used as a reinforcing material. Polypropylene (PP, manufactured by Prime Polymer Co., Ltd.) which is a representative thermoplastic resin was used as the base material. In addition, 2 wt% of maleic anhydride-modified PP (manufactured by Kayaku Akzo Co. Ltd.) was added as a compatibilizer. These materials were first kneaded using a twin screw kneading machine, and then molded by compression molding method, resulting in a ramie/PP composite plate with 200 × 200 mm^2 square and 1 mm thickness. The fiber content was 20 wt%.

2.2 Uniaxial Creep Load Test

An X-Y biaxial tensile tester (Capacity: 10 kN, manufactured by Kisankakoki Co. Ltd.) was used for the creep loading test. The prepared composite plate was processed into a rectangular piece and attached to the X-axis of the tester. Subsequently, a load of 1500 N was applied to the grip portion of the piece under five conditions of creep loading time of 3.75, 7.5, 15, 30, and 120 min. After that, the test pieces were cut out from the rectangular piece in the direction of 0 ^{o}, 22.5^{o}, 45^{o}, 67.5^{o}, and 90 ^{o} to the load direction. The dimensions of the test piece are 60 mm length, 15 mm width and 1 mm thickness. The obtained test pieces were tensile-tested using an Instron type tensile testing machine (Autograph IS-5000, Shimazu Co.). The tensile speed was set as 10 mm/min.

3. Discussions

3.1 Residual strength after uniaxial creep loading

Figure 1 shows the average residual strengths of the strip specimens after uniaxial creep loading. Results show that the conditions exceeding the solid line level, the tensile strength without creep loading, which in this case is 39.0 [MPa] (referred to as the initial level) are 7.5 min creep loaded at 0^{o}, 22.5^{o}, 45^{o} and 67.5^{o} cut-out angles (hereinafter referred to as 7.5 min-0 ^{o} load, etc.), which are higher than other residual strengths. The 3.75 min-0^{o}, 15 min-0^{o}, 15 min-22.5^{o} 15 min-45^{o} and 3.75 min-67.5^{o} loads are also higher, but others are found to be equal to or much lower than the initial level.

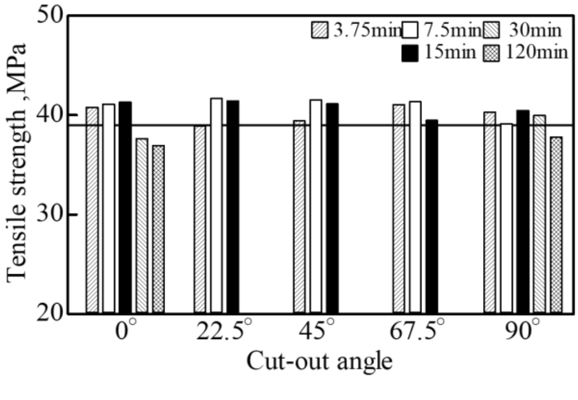

Fig. 1 Residual strengths after uniaxial loading (Solid line: ramie/PP strength level without creep loading)

3.2 Relations between residual strength and residual strain, residual strength and creep strain

In this study, we measured the residual strain after creep loading as well as the creep strain during creep loading. Figures 2 and 3 show the relations between residual strength and residual strain, residual strength and creep strain respectively at creep loading direction. Generally, it is thought that under the same loading conditions, as the creep loading time increases, the residual strain also increases. However, as seen here in Fig.2, there are data whereby the residual strain does not increase differently from the expected outcome. For example, in Fig. 2, on the top left side of the graph, the residual strains obtained for the loading time of 7.5min and 15min are relatively smaller than others, whilst having a high tensile strength. Therefore, it can be considered that there is a possibility of residual strength improvement when the residual strain is small. According to the previous studies [4,5], as ramie fibers undergoes repeated loading, the spiral-shaped cellulose micro fibrils in a ramie single cell aligns with the direction of the applied load, and their strength is improved. Thus, it can 7.5min-0º and 15min-0º. As for Fig.3, the overall mechanism occurred here for the loading time be perceived that the same improvement data obtained were varied and no significant correlation was seen. The strength improvement by the ramie fibers can be seen in the range of 0.4~0.5%.

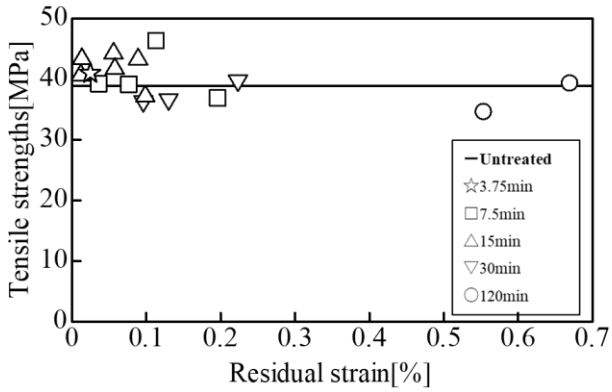

Fig. 2 Relation between tensile strength and residual strain in 0º direction after uniaxial loading (Solid line: ramie/PP strength level before creep loading)

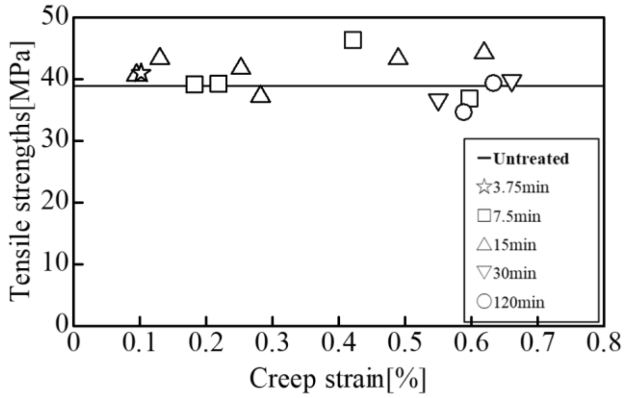

Fig.3 Relation between tensile strength and creep strain in 0º direction after uniaxial loading (Solid line: ramie/PP strength level before creep loading)

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