Improvement of mechanical properties of CFRP by adding nano-sized TiO_2 particles in matrix

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1. Introduction

Vacuum assisted Resin Transfer Molding (VaRTM) is an easier method for preparation of carbon fiber reinforced plastic (CFRP) than autoclave technique. However, the mechanical properties of the resulting CFRP is due to using low viscous resin. Recently, adding nano-sized oxide particles such as TiO_2 into resin is proposed to increase the mechanical properties of cured plastics [1]. In addition, it is also reported that adding nano-sized fillers such as carbon nanotube can improve the interlayer toughness of laminated CFRP [2]. Therefore, by adding nanoparticles in matrix, improvement of the mechanical properties of CFRP made of low viscous resin is expected.

The objective of this study is to improve of the mechanical properties of CFRP made by low viscous epoxy resin by adding nanoparticles. We attempt to prepare CFRP including nano-sized TiO_2 particles with VaRTM, and to evaluate the mechanical properties of resulting CFRP with three-point bending test.

2. Experiments

2.1 Materials

Epoxy resin used in this study is low viscous and two-liquid mixing type purchased from ThreeBond Co., Ltd. The main agent is TB2023, and cure agent is TB2131D. The viscosities of these two agents are 0.9 Pa·s and 10 mPa·s at 25ºC respectively. Unidirectional carbon fabric is UT70-60S (Toray Industries Inc.). The warp yarn is T700SC (number of filaments = 24000) and the weft yarn is glass fiber. The thickness of UT70-60S is about 1 mm. TiO_2 particles are Super Titania G-1 purchased from Showa Denko K.K. The TiO2 particles are spherical in diameter of 250 nm.

2.2 Preparation of specimens including TiO_2

Carbon fabric was cut into 170 × 170 mm^2 and was laminated on aluminum board. The laminates of carbon fabric were three plies and fiber direction of laminates was [0º/90º/0º] from the top plate. Flow path of epoxy solution and carbon laminates were covered with a vacuum bag. Inside of the bag was evaporated by using a vacuum pump from outlet side of the flow path. By vacuuming, the epoxy solution mixed with TiO_2 particles was impregnated into carbon laminates from inlet side of the flow path. After impregnation, the inlet and outlet of the flow paths were shuttered, and the inside of the bag was sealed. After sealing, the vacuumed set including CFRP was heated in oven at 100ºC for two hours. Then, cured CFRP was naturally cooled down to room temperature. Two types specimens, including TiO_2 particles and not including any particles, were prepared. The distribution of TiO_2 nanoparticles in CFRP was observed with energy dispersive x-ray spectroscopy (EDX).

2.3 Three-point bending test

CFRP specimens were cut into 100 × 15 mm^2 and the fiber directions of top and bottom laminates were longitudinal direction. Distance between both supporting points was 80 mm, and the testing rate is 5 mm/min. Bending strength and bending elastic modulus were calculated from the result, and influences of filler were evaluated.

3. Results and discussion

From EDX images, TiO_2 nanoparticles are majorly distributed in the gaps between carbon fiber tows in CFRP, and less exists inside tows. Fig. 1 shows the bending elastic modulus of CFRP. Improvement of bending elastic modulus of CFRP was confirmed by adding TiO_2 nanoparticles.

According to previous research of Li et al. [2] and Wang et al. [3], the oxide particles added in matrix have high interfacial adhesion with epoxy. This induces the stress transfer from matrix to the nanoparticles, which may improve the mechanical properties of CFRP. This result indicates that adding nanoparticles in resin can be a effective method to improve the mechanical properties of CFRP by VaRTM technique.

However, it is unclear that the relationship between nano-sized particles, matrix and carbon fibers in mechanical deformation. The investigation of the relationship in this complex system is required for more improvement in mechanical properties of CFRP.

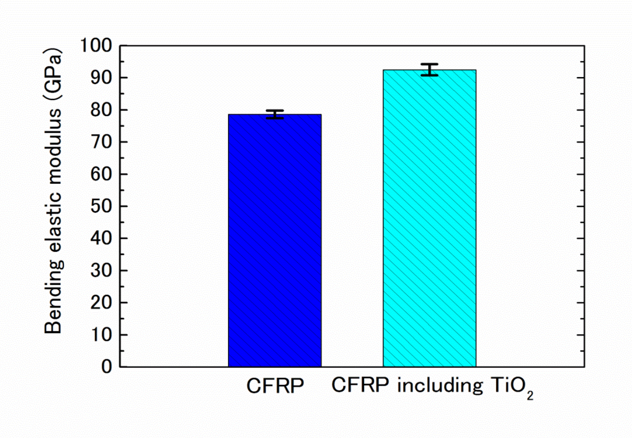

Fig. 1 Comparison of bending elastic modulus for neat CFRP and CFRP including nano-sized TiO_2

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