CFRPの表面処理によるCFRP/Steel接着性能比較

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Comparison of Adhesion Performance on CFRP/Steel via Surface Treatments of CFRP

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1. Introduction

For the structural applications, CFRP must have joints with dissimilar materials or CFRP in an assembly process. The joints could be made by the classical mechanical fastening methods such as a riveting, bolting, and clinching [1]. However, these methods must involve a penetrating hole through CFRP lamination, which can cause delamination and cracks in composite structures due to drilling during fastening process and stress concentration in use. Metallic fasteners are adopted mainly in those method, thus total weight of assembled structures also increase.

CFRP consists of several fabric layers made by numerous carbon fibers and a matrix material. The drilling process cut off the continuous fibers contributing to the tensile resistance in CFRP composite materials, which can be a potential risk of a safety issue in assembled structures. These can occur several joint failure modes on CFRP such as a net tension, shear-out, bearing, cleavage, tearing, pull-through, and fastener failure [2]. Moreover, the galvanic corrosion is occurred when CFRP directly contacted to a metallic material at joints [3]. From these reasons, using an adhesive at joints is more favorable since less stress concentration [4] with sealing and preventing corrosion effects.

In the adhesive joints, not only selecting an appropriate adhesive, a surface treatment on CFRP is a significant factor as well; because, surface state (i.e., surface contamination on CFRP such as greases and silicone) can arise the interfacial failure between CFRP/adhesives [5], and an appropriate surface treatment can enhance adhesion performance at joints [5-7]. There are various surface treatment techniques of CFRP (e.g., surface cleaning, sandblasting or sandpaper for surface roughness, plasma surface activation, primer coating, UV laser abrasion, and chemical grafting treatment for functional group on surface). And, appropriate treatment or its combination must be selected according to each usage of structural CFRP part as an adherent, e.g., for assembly stage and for repair stage. Moreover, balance among adhesion performance, structural reliability, and cost must be considered for the industrial use.

In this study, we investigated some basic treatment methods such as cleaning, sandpapering, and atmospheric plasma, and coating the surface with epoxy/filler mixture for applying surface roughness. Moreover, above methods were combined to suggest an optimal surface treatment for focusing on enhancing adhesion performance at the CFRP/adhesive interface. The combined methods were performed on CFRP surface prior to sampling the CFRP/Steel single lap joints, and the single lap shear tests were conducted. Morphology of the fracture surfaces and test results were investigated for discussing the effectiveness of the combined method.

2. Experimental

Materials in this study, i.e., CFRP, steel, and an epoxy adhesive, were fixed. CFRP plate (300×300×2.5 mm) was made by the prepreg compression molding (PCM) method using 13 laminated prepregs (Torayca F6347 prepreg, T300-3K 2/2, Toray Industries, Inc., Japan) at 150˚C 5min with 2.0 MPa. For the lap shear sampling, the plate was cut in 25×100 mm by a diamond cutter. Steel was purchased (25×100×1.5 mm, CR 340, Ever Steel Co., Ltd., Republic of Korea). An epoxy resin was purchased (KSR-177, Kukdo Chemical Co., Ltd., Republic of Korea), and a polyamide resin was purchased and used as a hardener (G-5022 Kukdo Chemical Co., Ltd., Republic of Korea). The epoxy resin and the polyamide resin were mixed by a mixer (ARE-310, THINKY Co., Japan) with a mixing ratio of equivalent weight to 1:1.1 at 1500 rpm 5 min. The epoxy adhesive mixture was degassed using vacuum chamber under 5 kPa for 5 min. A thickness of the adhesive in the test sample was controlled to 200 um using aluminum shim stocks. And, an overlap length was set to 12.5 mm. For the hardening process of the adhesive in an oven at 150˚C 20 min, each sides of the CFRP/steel joint samples were fixed using binder clips. Five same samples were prepared and the tests were conducted 5 times in each variation.

The cleaning process was conducted using an ultrasonic cleaner during 10 min within 95% ethanol. The sandpapering process was conducted using sandpapers (#100, 400, and 1000) with 10 round trip at 0.4±0.05 MPa. The atmospheric plasma (Plami Auto-100, APP Co., Ltd., Re-public of Korea) was conducted using Ar and O_2 gas with 90 W output during 26 s. The coating process was conducted with epoxy/filler mixture using an air brush (GP-50, Anest Iwata Sparmax Co., Ltd., Japan). The above treatments were carried out before the sampling process.

3. Results and Discussion

The single lap shear tests were conducted, and the results were obtained. The cleaning was set as a reference data (17 MPa, 100%ref.), which was pre-treated on all the other variations. Although the primer coating was poor (13 MPa, 75%ref.), the plasma improved the performance (22 MPa, 129%ref.) and the epoxy coating improved the performance (22.5 MPa, 132%ref.). The sandpapering treatments showed good performances (154 ~ 172%ref.). And, the results of the plasma pre-treated epoxy coatings showed comparable performances to sandpapering. In the presentation, more details including fracture shapes, roughness and etc. will be presented and discussed.

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