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Effect of Internal fractures under Tensile Loading on Gas Permeability of FRP

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Fuel cell vehicles are equipped with a high-pressure tank to store hydrogen as fuel. Current high-pressure tanks have a liner layer to prevent gas leakage. In the future, it is hoped that liner-less tanks will be realized to further reduce weight. However, the liner-less tank requires the FRP layer to have gas barrier properties. The ultimate goal of this study is to realize a liner-less tank using FRP with a matrix of resin with high gas barrier properties, the relationship between internal fractures after applied load and gas permeability was investigated. Furthermore, the elastic modulus of matrix resin was changed by varying the ratio of primer/curing agent. The effects of these differences on internal fracture and gas permeability were also examined. The reinforcement was carbon fiber plain woven fabric, and bisphenol F type epoxy and resorcinol epoxy were used as the primer, and MXDA was used as the curing agent. Specimens were prepared under three types: 8.8 g, 15.5 g, and 25.4 g of hardener per 100 g of primer. These specimens were referred to as C-9, C-15, and C-25. It is known that the elastic modulus of the resin increases with the amount of curing agent.

A prescribed tensile load was applied to investigate the internal damage after applying static stress and gas permeability. The specimens were subjected to strains of 30%, 50%, 70%, and 90%, with the strain at break being 100%. Gas permeation tests were then conducted. Oxygen was used as the test gas. Cross-sectional observation was then performed to quantify internal fractures. Changes in interfacial properties with the amount of curing agent were examined. Microdroplet tests were conducted to measure interfacial strength and DCB tests to measure fracture toughness as part of the evaluation of interfacial properties.

The relationship between the oxygen permeability and applied stress for each condition is shown in Fig.1. The amount of curing agent has little effect on the oxygen permeability of the resin. As the applied stress increased, the oxygen permeability remained constant for C-9. However, it increased for the other two type. Cross-sectional observations were carried out to clarify the cause of the difference in oxygen permeability after loading depending on the amount of curing agent. Crack density (number of cracks per unit area) and average crack length (average of randomly measured crack lengths) were measured in the cross-sectional observation.

Transverse cracks were observed in all specimens observed. Crack density increased with increasing applied stress and was significantly higher with C-25. The average crack length also increased with increasing applied stress, but there was no significant difference between the two type. The total crack length, which is the product of the crack density and the average crack length, was then determined. The relationship between the oxygen permeability and total crack length is shown in Fig. 2.The total crack length increased with increasing applied stress under both type. The longer the total crack length, the higher the oxygen permeability. There was no significant difference in the average crack length, and the crack density was significantly permeability higher with the higher amount of hardener. In other words, it is clear that the effect of crack density on the permeability is dominant.

The interfacial properties were examined to clarify the cause of the significantly larger crack density. The interfacial properties were examined to clarify the cause of the significantly larger crack density. There was no significant difference in interfacial strength, but fracture toughness decreased with increasing amounts of curing agent. Cross-sectional observation using a microscope reveals some long cracks, but the delamination at the fiber/resin interface that occurs around a single fiber can hardly be observed. Therefore, the crack density in C-25, where the cracks tend to elongate, is considered to be significantly larger.

When designing pressure vessels, FRP with a low amount of curing agent resin should be used on the inside to suppress cracks, and FRP with a high amount of curing agent resin should be used on the outside to provide rigidity.

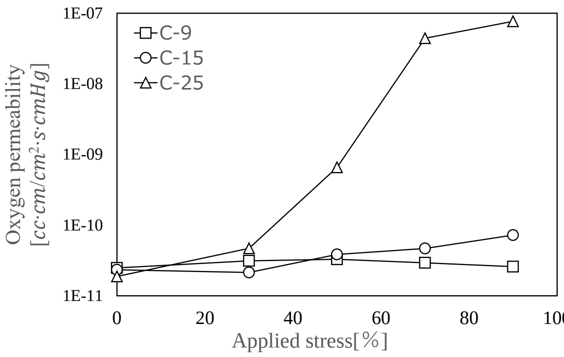

Fig.1 Relationship between oxygen permeability and applied stress

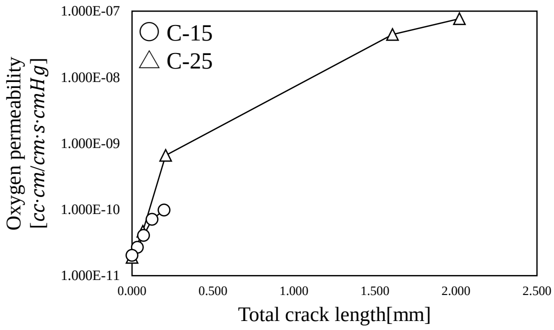

Fig.2 Relationship between oxygen permeability and Total crack length