EFFECT OF MOLDING CONDITION ON MECHANICAL PROPERTIES OF CFRP BY HP-RTM

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Introduction

CFRP (Carbon Fiber Reinforced Plastics) have been used in various fields. Boeing 787, BMW i3 and more products are famous for example of application of composite materials. There are a lot of different kinds of molding method for CFRP. Especially, RTM (Resin Transfer Molding) is paid attention around the automotive industry. It was considered that mechanical properties of CFRP should be same if reinforcing fiber, matrix, reinforcements and surface treatment were same whatever molding method was. However, it was revealed that mechanical properties were influenced by molding method. In recent study, interface property of FRP molded by RTM was lower than that of FRP by hand-lay-up, and microscopic damage of FRP by RTM was likely to occur.

Thermosetting resin composite material have high heat resistance, but long molding time was needed due to the chemical reaction. Therefore, HP-RTM (High Pressure Resin Transfer Molding) using fast cure type resin has been adopted. HP-RTM is a molding method that enables to shorten the molding time by using fast cure type resin pour into the molding die in a high pressure condition. However, the resin is transferred under the condition of high pressure and high speed in HP-RTM, interface property might be declined. The purpose of this study was to restrain microscopic damage by improving interface properties in CFRP molded by HP-RTM. In this study, seven kinds of CFRP were molded by changing pressure and resin, and static tensile property and crack propagation behavior were investigated.

Experimental method

CFRP specimens were molded by RTM. Table 1 is a list of specimens. NCF (Non-Crimp Fabric) was used as reinforcements and epoxy resin and vinyl ester resin were used as matrix resin in this study. Laminate configuration was $[0\text{-}90]_{4s}$. Molding pressure, which was pressure of resin injection, was set up 0 MPa, 5 MPa, and 10 MPa. Holding pressure was defined that kept pressure in mold after finishing resin injection. Seven kinds of specimens were molded by changing molding conditions and kinds of resin. Specimens were named by combining initials of matrix resin and molding pressure or holding pressure. Ep-0 was molded by Va-RTM. Ep-5, Ep-10, Vi-5 and Vi-10 were molded by RTM with pressing in laboratory scale. Ep-A and Ep-N were molded by HP-RTM in industry scale.

The observation of microscopic damage was investigated in tensile test and cyclic tensile test. Specimens were observed by optical microscope after reaching the target load. In cycling test, repeated load was defined as 40% of maximum load.

Result and discussion

For the convenience of the page, only a part of the result is described.

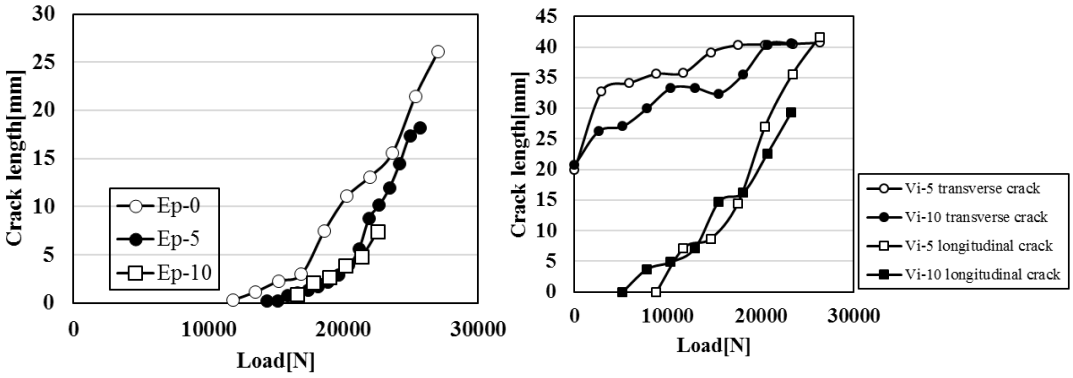
Only transverse crack occurred in specimen of Ep, but, not only transverse crack but also longitudinal crack occurred in 90 degree fiber bundles of specimen Vi. Relationship between total length of crack and load in tensile test for epoxy resin and vinyl ester resin was shown in Figs.1 (a) and (b). In the case of epoxy resin, the crack length decreased in same load condition by adding higher molding pressure. In the case of vinyl ester resin, transvers crack occurred before adding load. Both transverse crack length and longitudinal crack length decreased in same load condition by adding higher molding pressure. Figure 1(a) shows that Ep-10 is lower for fracture load than Ep-5 in spite of lower crack propagation in the order of Ep-10 and Ep-5. From observation results, the undulation of fiber bundle was higher in the order of Ep-10, Ep-5, and Ep-0. From this result, it was revealed that

undulation affected decreasing in tensile modulus and tensile strength, but propagation of microscopic damage was restrained by increasing molding pressure.

Relationship between length of crack and number of cycles was shown in Figs.2 (a) and (b). Both crack length decreased in same cycles by adding holding pressure. Transverse crack and delamination showed same tendency. It was revealed that holding pressure restrained crack propagation.

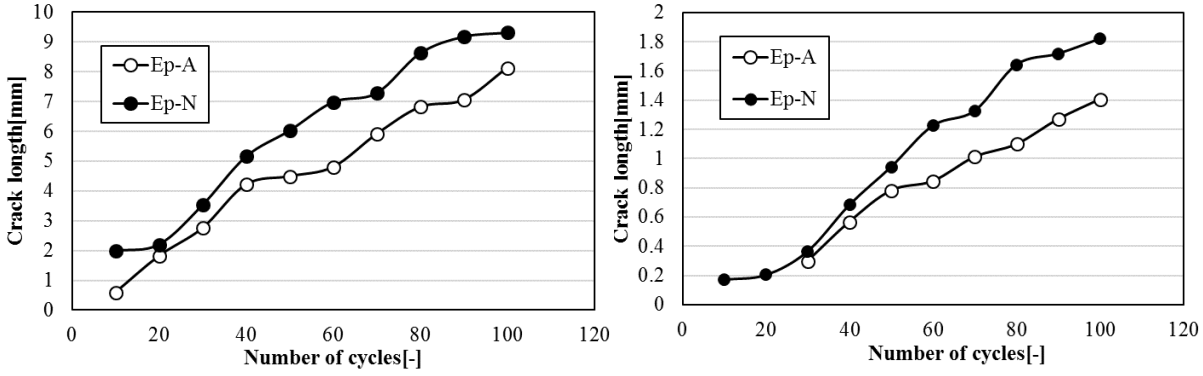
Table 1: *List of specimens.*

Specimen	Resin	Molding pressure[MPa]	Holding pressure
Ep-0	Epoxy	0(Va-RTM)	Not add
Ep-5	Epoxy	5	Not add
Ep-10	Epoxy	10	Not add
Vi-5	Vinyl ester	5	Not add
Vi-10	Vinyl ester	10	Not add
Ep-A	Epoxy	10	Add
Ep-N	Epoxy	10	Not add



(a) Specimens Ep. (b) Specimens Vi.

Figure 1: *Relationship between crack length and applied load.*



(a) Transverse crack (b) Delaminaton

Figure 2: *Relationship between crack length and number of cycles.*

Conclusion

In this study, effect of molding condition on mechanical properties of CFRP by RTM was investigated. In relation to crack propagation, the higher molding pressure and holding pressure restrained its propagation. But strength decreased due to the undulation of bundles under high pressure condition. From the result so far, high molding pressure was effective to restrain crack propagation, but a way of reduction to undulation should be established.