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Multi-scale analysis for mechanical properties of plain-weave carbon/epoxy composite using homogenization method

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1. Introduction

Recently, in various industrial fields such as the aeronautical, marine and automotive industries, composite materials having excellent Specific strength and specific stiffness are used [1-2]. The mechanical properties of composite materials is essential for structural design. On the other hand, although various studies have been conducted to predict the mechanical properties of composite materials, textile composite materials have geometrically very complicated shapes, and foreign substances, air bubbles, etc. generated during molding Due to the design variables of the textile composite materials, they becomes possible to see the properties such as heterogeneity, anisotropy and so on. Therefore, for the design of a structure, it is utmost important to evaluate the mechanical properties in consideration of the behavior of the constituents composite material [2-3].

In this study, multi-scale homogenization analysis was performed to evaluate the mechanical properties of carbon fabric composites. For this reason, first, micro level homogenization analysis was performed to estimate the effective mechanical properties, and their accuracy was proved by comparing the rule of mixture theory and the tensile test results. The macro level homogenization analysis method performed using the estimated effective properties of tow in micro level homogenization analysis.

2. Analysis and Experiments

2.1 Multi-scale homogenization method

Multi-scale homogenization analysis was performed using the commercially available software ABAQUS[4] to estimate the effective properties of the plain weave composites. Fig. 1 shows the micro level FE model, and the homogenization analysis was performed using the properties of the constituents (carbon fiber and epoxy matrix) in Table 1. And then, the macro level homogenization analysis was performed using the FE model in Fig. 2. This RUC(Repeated unit cell) model is designed according to the reference[5], and the effective properties at the volume fraction of 70% obtained by the micro level analysis of Table 2 is applied..

2.2 Result of tensile test

In order to confirm the mechanical properties of the plain weave carbon/epoxy material, the tensile tests were performed using an Instron 8516 model according to the ASTM D3039 standard.

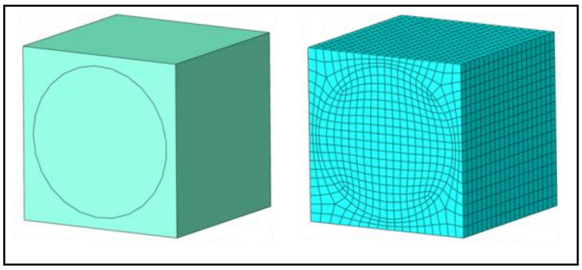

Fig.1 Square unit cells for carbon/epoxy composites

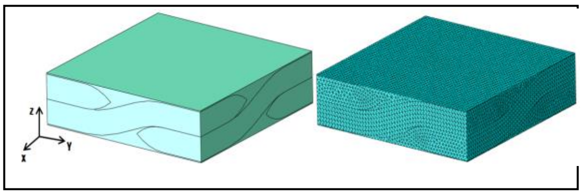

Fig.2 Repeat unit cells for fabric carbon/epoxy composites

Table 1 Material properties of fiber and matrix(TR50S/Epoxy)

	Fiber (Carbon)	Matrix (Epoxy)
Young's modulus	240 GPa	2.45 GPa
Shear modulus	93.385 GPa	0.907 GPa
Possion's ratio	0.285	0.350

3. Results and Discussion

The rule of mixture theory and the tensile test results were compared to confirm the accuracy of the micro analysis results. The actual volume fraction of fibers is about 70%, and the estimated properties have the errors of 2% and 13%, compared with the rule of mixture theory (Fig. 3) and tensile test results, respectively. In addition, it was possible to derive the effective properties of the plain weave composite material as a result of macro analysis. Through the above results, the proposed multiscale homogenization technique could be used to estimate the mechanical properties of the advanced composite materials.

Table 2 Material properties of tow and matrix(Tow/Epoxy)

	Tow	Matrix
$E_{11,micro}$	168.48 GPa	2.45 GPa
$E_{22,micro}$	22.418 GPa	2.45 GPa
$E_{33,micro}$	22.418 GPa	2.45 GPa
$G_{12,micro}$	6.144 GPa	0.907 GPa
$G_{13,micro}$	6.144 GPa	0.907 GPa
$G_{23,micro}$	3.792 GPa	0.907 GPa
$v_{12,micro}$	0.298	0.35
$v_{13,micro}$	0.298	0.35
$v_{23,micro}$	0.17	0.35

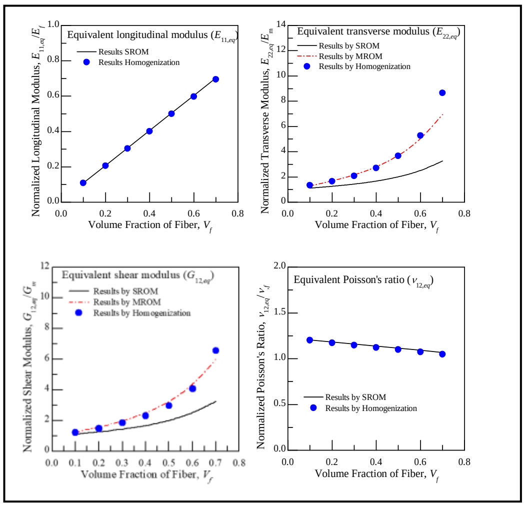

Fig.3 Homogenization analysis and rule of mixture comparison

4. Conclusions

In this study, we proposed the multiscale homogenization technique to evaluate the effective mechanical properties of the advanced composites

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