学 位 論 文 要 旨
Dissertation Summary

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論　文　名 :**Fatigue Behavior of CFRP Laminates with Initially Cut Fibers**
(Dissertation Title)

Recently, carbon fiber-reinforced plastics (CFRPs) have been widely applied to primary structure in the fields of transportation (aircraft and automobiles) and other fields as alternate materials of metals because a large fuel saving becomes possible by making structures light. When CFRP laminates are employed in automobiles structures, these components are frequently subjected to cyclic loads and vibrations, which may cause degradation of structural integrity because of fatigue damage. Thus, it is important to investigate the fatigue characteristics of CFRP laminates.

In addition, for design requirements and functional needs, an automobile is composed of many complexly shaped components. In general, it is quite difficult to fabricate such components using only conventional CFRP prepreg with continuous fiber owing to its poor formability. In contrast, discontinuous fiber-reinforced plastics fabricated by sheet molding compound (SMC) or injection molding have already been used as automotive parts since they have good molding flowability. However, their strength is much lower than that of composites reinforced with continuous fiber. Therefore, a new material, called unidirectionally arrayed chopped strands, was developed by introducing initially cut fibers (ICFs) into CFRP prepreg. The strength and uniformity of layer structure of the ICF laminate were found to be superior to those of SMCs. CFRP laminates with ICFs have good formability without large degradation of static strength, however, their fatigue behavior has not thoroughly been investigated thus far.

In this dissertation, first, fatigue behavior and damage progress of open-holed CFRP laminates with ICFs having interlayers are investigated. Three types of CFRP laminates were employed; a laminate without ICF fabricated using an autoclave (Continuous-A), a laminate with ICF fabricated using an autoclave (ICF-A) and a laminate with ICF fabricated using press molding (ICF-P). First, fatigue test was conducted to obtain S (maximum

stress)-N (the number of cycles to failure) curves in order to reveal fatigue strength. The fatigue tests for several specimens were interrupted at three prescribed numbers of cycles to observe damage progress. It is found that the Continuous-A laminate shows little strength degradation in the S-N curve by approximately 5 % at N of 10^6 while the fatigue strength of the ICF-P laminate is higher than that of the ICF-A laminate. Fatigue strength in both ICF laminates is decreased by approximately 30 % at N of 10^6. In contrast, the damage progress of the ICF-P laminate is the least among the three laminates while the delamination progress at both edges and around the hole in the Continuous-A laminate is the most prominent.

Second, the effects of fiber cutting angle on the fatigue behavior of open-holed CFRP laminates with ICFs are also investigated. Three kinds of fiber cutting angles (θ = 22.5, 45, and 90°) were applied to two types of quasi-isotropic ICF laminates; ICF-A and ICF-P. First, fatigue tests were conducted to obtain S-N curves in order to reveal fatigue strength. The fatigue tests of one specimen for each configuration were interrupted at three prescribed numbers of cycles to observe damage progress. Finally, a semi-empirical equation was proposed to predict delamination area just before the final failure against normalized applied stress. It is found from the experiment result that the fatigue strength in both laminates is the highest when the θ is the smallest (22.5°) although the static strength is the highest when the θ is 90°. In contrast, both laminates with the biggest θ (90°) exhibit the greatest delamination growth around the hole by cyclic loading.

Finally, fatigue behavior and damage progress of non-holed CFRP laminates with ICFs having interlayers are also investigated. Three types of CFRP laminates were employed; Continuous-A, ICF-A and ICF-P. First, fatigue test was conducted to obtain S -N curves in order to reveal fatigue strength. The fatigue tests for several specimens were interrupted at three prescribed numbers of cycles to observe damage progress. The results obtained from the fatigue test and damage progress observation of non-holed CFRP laminates indicated that the fatigue strength of the Continuous-A laminate is the highest among the three laminates while the fatigue strength of the ICF-P laminate is higher than that of the ICF-A laminate. However, the decrease ratio of fatigue strength at N of 10^6 is about 35% of its static strength, which is almost the same in the three laminates. In addition, the degree of damage in the ICF-P laminate is the smallest among the three laminates while the increase rate of the crack density and edge delamination is the greatest in the ICF-A laminate with thicker plies.

In conclusion, comparing the two ICF laminates in this study, it concluded that the fatigue strength of the ICF-P laminate in both open-holed and non-holed specimens had the greater fatigue strength compared to the ICF-A laminate. In addition, the fatigue damage progress in the ICF-P laminate is smaller than ICF-A laminate. Moreover, the ICF-P laminate with the smallest θ (22.5°) exhibited the greatest fatigue strength, while the ICF-A laminates with the largest θ (90°) exhibited the greatest delamination growth around the hole in open-holed specimens.