Caractérisation de l'endommagement de composites SMC à renfort carbone

Mechanical characterization of damage on a carbon fiber sheet molding compound composite

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1. Abstract

This communication presents the experimental analysis of the anisotropic effects, induced by the manufacturing process, of Advanced Carbon fiber Sheet Molding Compound composites (AC-SMC) subjected to quasi-static and fatigue loading. The impact of fiber orientation, induced by the thermo-compression process, on fatigue is investigated. For the tested configurations, it is reported that the macroscopic damage of AC-SMC RO exhibits a two-stage evolution without any damage saturation prior to the samples failure. Post-mortem X-ray radiography and SEM observations show that damage mechanisms occur as microcracks between and inside bundles, and they depend on the sample orientation. Experimental findings are compared with those of an equivalent glass fiber reinforced sheet molding compounds composite (A-SMC) with the following conclusions : (i) The degree of anisotropy was more pronounced for AC-SMC, due to the high dependency of the behavior on the manufacturing process induced orientation ; (ii) The damage evolutions of the two types of SMCs have displayed different kinetics, notably for the saturation stage which was not observed for the AC-SMC composite.

2. Damage evolution of AC-SMC composites

Sheet Molding Compounds (SMCs) materials are widely employed in the automotive industry for the design of large semi-structural automotive components, thanks to their high strength to weight ratio and their flexibility [1, 2]. To further improve the mechanical performances of structural parts, Advanced Carbon Sheet Molding Compounds (AC-SMC) have been developed by Plastic Omnium. The key characteristics is a high content of carbon (up to 55%). According to their target application, AC-SMCs are subjected to mechanical loads, quasi-static as well as repeated loadings in all their lightweight applications. To design components subjected to such mechanical loads, the damage evolution in AC-SMC composites should be understood and characterized. The key factors that influence fatigue life are found to be the process induced microstructure and the reinforcement orientation [3], the nature of the matrix [4], the mean stress [5], loading frequency, temperature and humidity.

The present study is dedicated to the experimental analysis of damage in AC-SMC composites. Two critical configurations are tested (Randomly Oriented, RO, and Highly Oriented, HO), considering three different orientations (0°, 45°, 90°) with respect to the material thermo-compression flow direction. The experimental findings obtained on two configurations of AC-SMC composites (namely Randomly Oriented, RO, and Highly Oriented, HO) are compared with those of an equivalent glass fiber reinforced A-SMC. The evolution of macroscopic damage is recorded during quasi-static tests and at several stages of the fatigue tests. Tested AC-SMC consists of vinyl-ester thermoset matrix reinforced by short carbon bundles having a length of 25.4 mm. According to the thermo-compression process, the bundles present a specific orientation. The material tested contains a high overall content of carbon reinforcement (55% in weight ratio, corresponding to 44.9% in volume ratio). AC-SMC do not contain fillers, contrarily to classical glass fiber-reinforced composites SMCs.

3. Conclusions

Based on the experimental campaign, the following concluding remarks are drawn [6] :

— Both configurations of AC-SMC exhibit a quasi-brittle in-plane anisotropic response. Note that conventional glass fiber A-SMC composites, in RO configuration, presents an in-plane isotropic behavior. This non- conventional finding is associated with the manufacturing process-induced microstructure specific for AC-SMC.

— Microscopic investigations using post-mortem SEM and X-rays radiographies show that the damage modes occur as microcracks at two levels (inter-bundles and intra-bundles). In addition, the macroscopic damage evolution exhibits a two-stages evolution (initiation and propagation) and no saturation was observed prior to the samples' failure, conversely to the damage evolution observed on A-SMC RO.

— In terms of ultimate stress, the difference between the HO and RO is more pronounced for the AC-SMC samples than for the A-SMC samples. This difference is amplified especially for AC-SMC at 45°and 90°.

— The macroscopic damage of AC-SMC RO under fatigue loading shows a two-stages evolution similar to that observed for quasi-static loading, and similar damage modes.

Références

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