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ORIGINAL PAPER

The effect of nanoparticles in single-lap composite joints studied by experimental and numerical analyses

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Abstract This study aimed to investigate the effect of nanoparticles on the strength of single-lap nanocomposite joints. Three different types of specimens were studied, each of which contained 1 wt% of carbon nanotube in the adhesive. The adherends included three different percentages of nanoclays, namely 0, 5 and 7 wt%. The material used here was glass fibers/epoxy, with epoxy as the matrix. After fabrication of the laminates, they were stuck together by epoxy resin containing 1 wt% of carbon nanotube. Different tests were also conducted to analyze the specimens. These tests included X-ray diffraction (XRD), scanning electron microscope (SEM) and tensile test. In the XRD test, the presence of glass fiber, epoxy resin and nanoclays was verified and in the SEM test, the distribution of nanoclays into the laminates was investigated and finally the strength of the joints with different nanoparticles was examined by tensile test. In addition, a finite element (FE) analysis was also incorporated and the results of this method were verified by the experimental results. To perform the FE analysis, Young's modulus of the laminates and the adhesive were both required. Therefore, a tensile test was conducted to obtain the Young's modulus of the adherends and the elastic modulus of adhesive was obtained from the data existing in the literature. Finally, the results from FE analysis and the experimental tests were compared with each other and a good agreement was observed. It was finally concluded that the specimen comprised of 5 wt% nanoclays had the best performance among the three.

Keywords Nanoclay · Carbon nanotube · Adhesive joint · Finite element analysis · Glass/epoxy composites

Introduction

The use of composites rather than metals in complex structures accommodates less number of components due to the low weight and easier assembling of the composites. In the design of composite structures it is sometimes necessary to join the structures together so that the integrity of the structure is retained while subjected to different loads in different environments. To join metals together might require riveting, bolting, gluing, brazing, soldering, etc. However, for polymer matrix fiber-reinforced composites these types of joining are mostly constrained to adhesive bonding and mechanical fasteners (bolts and rivets).

To investigate the behavior of adhesive and mechanical joints, different studies have been carried out. Kwang-Soo et al. [1] investigated the failure process and strength of a single-lap composite joint. They compared the co-curing and secondary adhesion methods. Failure in the first method was attributed to delamination which is actually a less strong joint in comparison with the joints produced by secondary adhesion method. Beylergil et al. [2] investigated the behavior of single-lap composite joints with inter-adherend fibers. Their results showed that the presence of these fibers would strengthen the ultimate strength and tolerance of the joint toward damage. The effects of pin on the damage tolerance of bolted joints were reported by Li et al. [3]. They strengthened the holes with different sizes of

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