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Technical Report

The evolution of transverse stresses in hybrid composites under hygrothermal loading

Z. Sereir [a,b,1], E.A. Adda-bedia [b,*], N. Boualem [a]

[a] Laboratory of Composite Structures and Innovating Materials, Faculty of Mechanical Engineering, University of Sciences and Technology of Oran Mohamed Boudiaf, BP 1505 El M'naouer, USTO, Oran, Algeria

[b] Materials and Hydrology Laboratory, University of Sidi Bel Abbes, BP 89 Ben M'hidi City, 22000 Sidi Bel Abbes, Algeria

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ABSTRACT

This paper presents a hygrothermal analysis of the hybrid composites under the effect of the cyclic environmental conditions in order to determine the transient transverse stresses of the $[\theta/-\theta]_S$ stacking sequences. Hybrid composite is used to consider an appropriate isolation against the cyclic environmental conditions, as well as the reduction of the hygrothermal transverse stresses at both edges of the plate. To reach this aim, we used initially, the computer code W8gain developed by Springer for the determination of the moisture concentration at the end of each cycle. Thereafter, a computer code is developed to compute the hygrothermal transient stresses with implicit variation of temperature and moisture concentration after each cycle. To reduce the transverse stresses, some cases of hybrid composites are proposed. For each case, the thickness of each material constituting the hybrid plate (T300/5208 or AS/3501-5) is gradually varied, but the total thickness of our plate remains unchanged. This thickness variation enables us to find an appropriate hybrid plate which predicts an optimal reduction of hygrothermal transverse stresses; consequently an increase in durability of our hybrid plate.

1. Introduction

In the last recent years carbon fibers reinforced plastics are greatly used in various applications of industry, because of these significant advantages. Their advantages are distinguished in the high rapport between strength-weight and modulus-weight ratios. These materials are also characterized by their, superior corrosion resistance and low thermal conductivity [1,2]. The matrix which ensures a good junction between fibers and which absorbs the impacts during collisions undergoes an important degradation when it is exposed to the environmental conditions like moisture and temperature. This degradation becomes more critical with the simultaneous increase in temperature and relative humidity [3–6].

A change in temperature and moisture content usually induces hygrothermal forces and moments resultants as well as dimensional changes in the composite body. In addition, the thermal stresses produced during the cooling process of composite after cure at elevated temperature could be so combined with hygrothermal stresses induced moisture absorption. The resulting hygrothermal and mechanical stresses combined with each other may be sufficiently large enough to influence the failure of the composite structures and thus should not be neglected in modern design analysis lifetime estimation [7–10]. However, the available literature gives us an outline on the various ways in which the effects of temperature and moisture are manifesting. Hu and Sun [10] found that moisture contents in polymeric composite proportionally relax its elastic compliance similar to that of increasing temperature. It is, therefore, significant and beneficial to find the relation between moisture and temperature effects on physical aging of polymeric composites. Earl and Shenoi [11] presented an analytical and experimental approach to determine the moisture uptake mechanisms in closed cell PVC foam under fresh-water immersion. A comprehensive understanding of the aging mechanism for the foam has been proposed. The multi-stage process was attributed to diffusion, influenced by internal stress relaxation and the geometry of the local cell structure. From studies carried out by Bradley and Grant [12] on the sea water effect at the interface of the laminated plates, it noticed that a damage between layers due to shear stresses caused by moisture absorption. Harper and Weitsman [13] presented an experimental and theoretical investigation of moisture effects in graphite/epoxy composites. Thereafter, it [14] developed a mathematical model for the coupling between moisture diffusion and damage in fiber-reinforced, polymeric composites. The developed model employs concepts of continuum damage theory to describe those debondings. Smith and Weitsman [15] noted that for polymer matrix composites immersed in the sea water; there is an important difference between the moisture concentration in matrix and at the interface fiber–matrix. Zheng and Morgan [16] reported that at a critical

* Corresponding author. Tel.: +213 (0) 48544100.
E-mail addresses: cimsc09@univ-usto.dz, serzou@hotmail.com (Z. Sereir), addabed@yahoo.com (E.A. Adda-bedia).
[1] Tel.: +213 (0) 41584323.

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