

Fatigue behavior and life assessment of CFRP structures under global non-proportional multi-axial loading conditions

Popular Science abstract

The growing demand in the composite materials market is caused by continuously developed manufacturing processes. This demand is led due to the prominent properties, which these materials show such as high specific strength, low density, high resistance to corrosion, fatigue, and chemical environment. Moreover, the design flexibility allows producing new more complicated geometrically sized parts and objects applying modern hybrid materials. It is worth mentioning a few examples such as wind turbine blades, transmission shafts, high-pressure vessels, or plane airframes. Considering these applications, it is assumed that they are subjected to various cyclic loads. For instance, the transmission shaft is subjected to torsion and bending loadings. These conditions significantly influence the operation service of the objects. Because of the development of composite materials in structural engineering, a detailed design process that provides safety and reliability in service is required.

This research focuses on the characterization of fatigue behavior. The specific layered material is under investigation, carbon fiber reinforced polymer (CFRP) subjected to axial force and torsion, which is phase shifted. Knowledge of this behavior allows assessing the fatigue life based on the energy approach. The literature provides several fatigue criteria, which do not cover all factors that influence the fatigue degradation of layered structures. In this project, the redeveloped fatigue criteria based on the energy approach will be provided to assess the lifetime taking into account the investigated parameters. This aspect of the work can significantly govern the design process of such constructions.

The methodology of the project can be divided into the experiment and analytical phases. The first phase includes experimental labor, that is, a preliminary study for fatigue life assessment. In this part, the cylindrical CFRP structures manufactured using the filament winding method will be subjected to tension/torsion loading conditions. The servo-hydraulic test system equipped with special grips provides adequate loading conditions. The second phase would be connected with fatigue behavior assessment. The validation of fatigue hypotheses is available in the literature and an attempt to develop an own fatigue criterion having regard to the examined parameters will be examined, which will assess the fatigue life of the structure.

The experimental part will be enriched with nondestructive (ND) methods to examine the failure mechanisms. In composite materials, several failure mechanisms may occur, for instance, delamination, debonding, matrix cracking, or fiber pull-out. The ND methods allow determining the defects that appear due to the technological process and developing them during the experiment. Ex-situ computed tomography is a reliable method to determine pores and inclusions that are in the wake of the technological process. Furthermore, in-situ analysis shows the evolution of appearing defects and failure mechanisms during the fatigue test. Additionally, to measure strain during the test, the digital image correlation (DIC) device will be used. It will also provide information about defects occurring on the external surface of the sample.

The proposed project allows filling the existing gap in the literature comprehensively, from the strength analysis leading to fatigue criteria with highly predictable reliability.