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NONLINEAR THERMO-MECHANICAL FINITE ELEMENTANALYSIS OF POLYMER FOAM CORED SANDWICH STRUCTURES INCLUDING GEOMETRICAL AND MATERIAL NONLINEARITY

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ABSTRACT

Polymer foam cored sandwich structures are being extensively used for a wide variety of applications including boat hulls and ship structures, wind turbine blades as well as for structural applications in the fields of transportation and aerospace. The primary reason for this is their high stiffness to weight and strength to weight ratios, which make them especially effective for resisting bending and buckling loads. Sandwich structures are often exposed to severe service conditions that include elevated temperatures acting simultaneously with the mechanical loads. Polymer foams cores are sensitive to elevated temperatures, since typically they display significant degradation of their mechanical properties when exposed to temperatures experienced within the typical range of service temperatures imposed by operation or the environment. For example, PVC foams lose all stiffness and strength at about 80–100^{o}C, while PMI foams lose the heat distortion resistance at about 200^{o}C. Thus, simultaneous application of thermal and mechanical loads on sandwich structures may lead to a complete loss of structural integrity, often by loss of stability, due to the interaction between thermal and mechanical loads. The research reported in [1- 3] shows that thermal degradation (softening) of polymer foam core materials exerts a significant influence on the performance of sandwich structures. More specifically, the degradation of the core properties with rising temperature lowers the buckling resistance [2, 3]. In addition, when external mechanical loads act simultaneously with thermal loads, the material degradation may shift the response from being linear and stable into being nonlinear and unstable [3]. This is particularly pronounced when thermal gradients are present through the thickness of the sandwich panel, and when the heated (warmest) face sheet is subject to compressive loading/stresses [3]. The results

reported in [1-3] are based on the so-called High-order Sandwich Panel Theory (HSAPT) approach, which provides a method for analysing nonlinear problems involving sandwich structures. Despite its advantages the HSAPT approach is largely intractable for the analysis of sandwich structures with complex shapes and boundary conditions. Problems involving complex shapes/geometries and boundary conditions typically requires the use general finite element analysis (FEA) tools to analyse, but the large face-core stiffness ratios in sandwich structures leads to numerical instabilities and significant element distortions of the FEA models [4]. Moreover, the face-core stiffness ratios will increase with increasing temperature leading to even more severe convergence problems for the FEA solutions [4].

In this paper, polymer foam cored sandwich structures with fibre reinforced composite face sheets subjected to combined mechanical and thermal loads will be analysed using the commercial FE code ABAQUS® incorporating both material and geometrical nonlinearity. Large displacements and rotations are included in the analysis. The full nonlinear stress-strain curves up to failure will be considered for the polymer foams at different temperatures to study the effect of material nonlinearity in detail. A modified Arcan fixture is used to load the polymer foam specimens, which is enclosed in a thermal chamber. Digital Image Correlation (DIC) is used to obtain full-field strain distribution, from which the nonlinear tensile, compressive and shear stress-strain curves to failure are derived at different temperatures. The material nonlinearity primarily includes plasticity, but also nonlinear elasticity and viscoelasticity effects are included in stress-strain response of the core. Core material nonlinearity is especially important in the vicinity of the load introduction points, and will increase in relative magnitude with increasing temperature. The paper will present preliminary results including equilibrium curves obtained with or without inclusion of material nonlinearity (including geometric nonlinearity in both cases). A discussion of the procedure and strategy for obtaining convergent FEA solutions for deriving the thermo-mechanical behaviour of foam cored sandwich structures is provided, which accounts for both geometrical and material nonlinearities.

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