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Mechanical Behaviour and Numerical Modelling of Epoxy Matrix Composite Doped with Carbon Nanoparticles

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ABSTRACT

Our studies investigated the elastic-plastic properties and strength of epoxy resin matrices promoted with different concentrations of carbon-based nanomaterials. The graphene nanopowder xGNP-M-5 (XG Science), in the manufacture of epoxy L20/graphene composites, specific amounts of resin were mixed with hardener and graphene and oxidized graphene in 0.1, 0.5, 1, 2, 4% by weight, prepared. The resulting mixtures were degassed under vacuum (-1 bar) and poured into silicone moulds. The composites were left in the fume hood to cure for 24 hours and then heated at 120°C for 96 hours. The mechanical response of epoxy networks was investigated under uniaxial tension and compression at low and an intermediate strain rates, using the MTS 858 testing machine and the DIC (Digital Image Correlation) technique. In the uniaxial compression tests, cylindrical specimens with the dimension ratio of 1.5: 1 (height: diameter) were used. In the axial tensile tests, flat samples cut from lamellas with a thickness of 2 mm were used. The actual stresses and actual strains were determined, assuming the incompressibility of the material. The tests were carried out on at least three samples for each type of epoxy graphene composites. Young's modulus was determined for the linear part of the stress-strain relationship for strains ranging from 0.1 to 0.3%. The resin's deterioration process results from developing a multiscale micro-shear bands system leading to inelastic strains terminated by cracking in samples with deformation of 4% resulting in a sharp drop in stress. Based on these observations, a model describing the inelastic behaviour of nanocomposite was proposed, modifying the viscoplastic flow equation by introducing the shear banding contribution function. Finite element (FE) simulations of the conducted experiments were performed with ABAQUS software. In simulations the strain rate dependent modified Perzyna (MP) model with Mises yield criterion with a strain hardening law was accompanied with shear bands degradation ductile criterion to describe the nanocomposite material properties. The stress and strain distributions for different uniaxial tension and compression considered were calculated using data obtained from the experiments. A range of parameters, like hardening, shear bands initiation strain, etc. which play an important role in the simulation, were studied. The deformation process of nanocomposite revealed that in the case of the 0.1wt.% of nanoparticles the strength stress is highest. With the shear bands degradation criterion during uniaxial loading leading to accurate prediction of the epoxy nanocomposite performance in numerical simulations.