Summary/ Abstract

The aim of this thesis is to scrutinize the mechanical properties and stress analysis of carbon nanotube (CNT) coated–fiber multi-scale hybrid composites, which is henceforth referred to as CCFM hybrid composites, through proposing analytical and numerical methods. Firstly, the mechanical properties of the CNT coating region have been calculated at the lower scales, nano, and micro scales. The models comprise a core fiber, CNT coating region (CCR) and surrounding matrix, in which the coating region around the core fiber encompasses CNTs and matrix.

In addition, different types of coating regions in terms of configurations of the grown CNTs on the fiber surface are constructed consisting of axially, radially, and randomly oriented CNTs. The mechanical properties of various coating regions are calculated employing the Eshelby–Mori–Tanaka method in conjunction with an equivalent continuum approach. Having obtained the properties of the CNT structure and the coating regions at the lower scale, the models are then established at macro scale and the multi-scale modeling is conducted covering various effective parameters from nano-to macro-scale.

In the next step, interfacial radial and axial stresses of CCFM hybrid composites are acquired through multi-scale finite element analysis. The results reveal that: (I) a remarkable influence of CNT coating on the fiber-matrix interfacial properties, particularly in the composites containing axially and randomly oriented CNTs, (II) considering two hybrid systems, composites with CNTs coated–fibers demonstrate notable improvements in the interfacial behaviors than those with CNTs in matrix, (III) the pronounced effect of non-bonded interphase region on the interfacial properties, while less significant influence on the Young's moduli is observed.

Moreover, the influence of carbon nanotube coated-carbon fibers on thermal residual stresses of multi-scale hybrid composites is investigated through analytical approach. Utilizing the total energy minimization method, the closed- form solution of the thermal residual stresses of hybrid composite is obtained. The results disclose a noteworthy influence of CNT–coating on the reduction of interfacial stresses which precludes debonding at interface and attenuates the effect of thermal expansions mismatch between the carbon fiber and matrix. Furthermore, the results demonstrate that unlike radially oriented CNTs, the existence of axially and randomly oriented CNTs at the coating region has a remarkable diminishing effect on residual interfacial stresses. It is also shown that increasing the coating thickness leads to reduction of maximum interfacial stresses even at a constant CNT volume fraction.

With the aim of investigating the bending analysis of CCFM hybrid composite beam, the Refined Zigzag Theory (RZT) is utilized and developed for both laminated and sandwich carbon nanotube coated–fiber multi-scale composite (CFMC) beams. Having implemented the multi-scale modeling, the results are then fed into the RZT. Considering two types of CNT coating around the core fiber consisting of axially aligned' and 'randomly oriented' CCRs (hereafter referred to as ACCR and RNCCR, respectively), the bending stress analysis is carried out

through the RZT taking into account simply-supported beam with transverse sinusoidal loading. The results reveal a pronounced reduction in transverse displacement in laminated and sandwich CCFM composite beams with respect to conventional composite beams. Moreover, by employing a combination of ACCR and RNCCR for the layers in the sandwich CFMC beams, a pronounced decrease in the transverse shear stress of the core medium is demonstrated which can postpone the core shear failure in the sandwich structures. In addition, effect of CCR types, CNT volume fraction, core fiber material and orientation, and CNT coating thickness are entirely assessed on the bending analysis of CCFM composite beams.

By way of conclusion, it should be stated that the proposed techniques in this thesis could be utilized as an effective, accurate and viable tools for future design and analysis of CCFM hybrid composite structur