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Digital Image Correlation Based Mechanical Response Characterization of Thin-Walled Composite Cylindrical Shells

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Abstract : Anisotropy dominated continuous-fiber composite materials have garnered attention in numerous mechanical and aerospace structural applications. Tailored mechanical properties in advanced composites can exhibit superiority in terms of stiffness-to-weight ratio, strength-to-weight ratio, low-density characteristics, coupled with significant improvements in fatigue resistance as opposed to metal structure counterparts. Extensive research has demonstrated their core potential as more than just mere lightweight substitutes to conventional materials. Prior work done by Mahadev and Chan focused on formulating a modified composite shell theory based prognosis methodology for investigating the structural response of thin-walled circular cylindrical shell type composite configurations under in-plane mechanical loads respectively. The prime motivation to develop this theory stemmed from its capability to generate simple yet accurate closed-form analytical results that can efficiently characterize circular composite shell construction. It showcased the development of a novel mathematical framework to analytically identify the location of the centroid for thin-walled, open cross-section, curved composite shells that were characterized by circumferential arc angle, thickness-to-mean radius ratio, and total laminate thickness. Ply stress variations for curved cylindrical shells were analytically examined under the application of centric tensile and bending loading. This work presents a cost-effective, small-platform experimental methodology by taking advantage of the full-field measurement capability of digital image correlation (DIC) for an accurate assessment of key mechanical parameters such as in-plane mechanical stresses and strains, centroid location etc. Mechanical property measurement of advanced composite materials can become challenging due to their anisotropy and complex failure mechanisms. Full-field displacement measurements are well suited for characterizing the mechanical properties of composite materials because of the complexity of their deformation. This work encompasses the fabrication of a set of curved cylindrical shell coupons, the design and development of a novel test-fixture design and an innovative experimental methodology that demonstrates the capability to very accurately predict the location of centroid in such curved composite cylindrical strips via employing a DIC based strain measurement technique. Error percentage difference between experimental centroid measurements and previously estimated analytical centroid results are observed to be in good agreement. The developed analytical modified-shell theory provides the capability to understand the fundamental behavior of thin-walled cylindrical shells and offers the potential to generate novel avenues to understand the physics of such structures at a laminate level.

Keywords : anisotropy, composites, curved cylindrical shells, digital image correlation
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