Shear Effects in the Homogenisation of Slender Composite Wings

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The use of advance composite materials in aeronautical structures has increased dramatically over recent years. Consequently, the complexity of the design stage has risen and dynamic simulations of vehicles with flexible wings require computationally-viable models, made with homogenised properties. This work proposes a methodology to obtain the transverse shear stiffness of a slender periodic composite structure using a unit cell description and carefully-chosen boundary conditions. In a previous work [Dizy, Palacios & Pinho, 2012. *AIAA* 2012-1949] we showed a finite-element based procedure to calculate the classical elastic constants (extension, bending in two directions and torsion). Here, this will be extended to calculate the transverse shear stiffness in two directions, which results in a complete and more natural description of the beam with all six degrees of freedom. The addition of the shear variables is non-trivial as this loading case does not define a spanwise periodic displacement field, with a linearly varying bending moment (consequence of the constant shear force throughout). To circumvent this, the strains and curvatures are chosen so that, when the stiffness (or compliance) matrix is converged, the resulting forces and moments are statically determined; this results in a load description similar to the fundamental states in the work from Kennedy and Martins [2012. *IJSS*,49:54-72]. This work is an extension of their 2D midplane sections and adapted to be used with standard finite element code.

This method is an alternative to the Variational Asymptotic Method which was originally restricted to axially invariant cross sections and recently modified to account for spanwise heterogenity [Lee & Yu, 2011. *J of Comp and Struc* 89: 1503-1511] making it closer to the two-scale formal asymptotic approach [Buannic & Cartraud 2001a, *IJSS* 38:7139-7161; Kim & Wang 2010, *J of Vib and Acoust* 132, 041003]. The drawback of these methods is the difficulty of finding suitable boundary condition or adapting them to conventional engineering models. Previous work in the literature has also been focused in using commercially available finite element packages, but has omitted either material anisotropy [Jonnalagadda & Whitcomb, 2011. *AIAA* 2011-1881] or not included the shear components [Cartraud & Messager, 2006. *IJSS* 43:2403-2438]. The proposed description is compact and easy to apply to engineering models that can be used in Industry while retaining the rigour of a full 6x6 stiffness matrix and allowing for composite materials and periodically varying cross sections. Additionally, the use of a general-purpose finite element package makes the modelling of the unit cell efficient and versatile (allowing different parts and tie constraints), offers the possibility of built-in tools such as a buckling analysis to be used and requires little additional training for someone already familiar with them.

The final paper will present a full description of the procedure to identify the transverse shear load states on the unit cell, including details of the implementation in a finite-element solver (Abaqus). Then it will investigate its performance in various numerical test cases compared to the full-beam solution. It will also include further examples of the diverse capabilities of the method (such as buckling or stress/strain recovery) which confirm its potential as a design-stage tool for slender aerospace structures such as aircraft wings, helicopter rotor blades and wind turbine blades.

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