Equivalent single layer models of laminated plates and shells: achievements, limitations and future directions

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Over the past decades, numerous theoretical approaches have been proposed to model mechanical behaviour of composite laminated plates and shells. Among the various models developed, two-dimensional Equivalent Single Layer models (ESL) are particularly attractive due to their relatively low computational cost. Being two-dimensional, these models are generally based on theories of homogeneous plates and shells; however, their application to laminated composite structures requires appropriate modelling strategies to capture characteristic phenomena such as high transverse shear flexibility and the variation of stiffness through the thickness [1-3]. In addition, individual layers in laminated composite structures exhibit orthotropic behaviour, leading to markedly different mechanical responses depending on the direction of the applied loading. Variations in stiffness and strength along the fibre direction, transverse to the fibres, and in shear result in distinct deformation patterns and load-transfer mechanisms under different loading conditions. This imposes the use of appropriate constitutive models and failure criteria capable of capturing the direction-dependent, anisotropic response of individual layers.

This keynote lecture provides a comprehensive overview of the current state of the art in ESL modelling of laminated plates and shells, drawing on key contributions from the composite structures' community [1-2] as well as selected developments proposed by the author's research group. Different kinematics descriptions adopted within ESL formulations are examined and their implications for mechanical response prediction are discussed [3]. Particular attention will then be devoted to the capabilities and limitations of ESL models in the analysis of damage and failure in laminated shell structures, including the application of different failure criteria [4].

[1] E. Carrera, Compos. Struct., 50, 183-198, 2000. https://doi.org/10.1016/S0263-8223(00)00099-4

[2] A. Tessler, M. Di Sciuva, M. Gherlone, J. Mech. Mater. Struct., 5, 341–367, 2010. https://doi.org/10.2140/jomms.2010.5.341

[3] I. Kreja, A. Sabik, Acta Mech. 230, 2827–2851, 2019. https://doi.org/10.1007/s00707-019-02434-7

[4] J. Chróścielewski, A. Sabik, B. Sobczyk. W. Witkowski, Compos. Struct. 261, 1-15, 2021. https://doi.org/10.1016/j.compstruct.2020.113537