cope with distorted element shapes. These variable kinematics plate models and the corresponding displacement-based, mixed and hybrid FE, are all implemented as User Elements into the commercial software Abaqus. A dedicated Python plugin guides the user to the proper model definition, indicating all parameters required to identify the plate FE. Preliminary results are shown to highlight the robustness and accuracy of the proposed elements. The SGUF approach is particularly attractive for modelling single- or multi-core sandwich panels with composite skins.

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abst. 15628
Room 1
Wednesday
July 3
09h40

Shear deformable beam model for stability analysis of beam type structures with composite cross sections

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This paper presents a shear deformable numerical model for the large displacement analysis of beam type structures. Shear deformation effects are accounted for the composite cross-section considering bending-torsional coupling effects. Cross section characteristics are calculated based on the reference modulus, with ability to model different material configurations. A numerical algorithm for calculating the geometric characteristics of a composite cross-section is developed. Various material configurations are considered. This procedure is incorporated in the 1D beam model for the nonlinear stability analysis, previously developed by the authors. Large rotations are allowed, but small strains are assumed to occur. Several benchmark examples are demonstrated for verification purposes.

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abst. 15663
Room 1
Wednesday
July 3
09h00

Fast analysis of panels with curvilinear stringers

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New manufacturing techniques, such as addictive manufacturing, offer the chance of considering novel structural configurations and concepts, in the past hardly realizable, that could help to achieve improved efficiency. Structural panels commonly employed in aerospace construction-either in metallic and composite designs-are classically designed using rectangular panels and orthogonal stiffening elements, i.e. stringers and frames or ribs. While these architectures can be optimal for many loading conditions, the adoption of stringers running along non-straight, curvilinear paths can be exploited for shaping the nodal lines of the buckling modes, as well as tailoring the load paths with additional freedom. Previous studies indicated potential benefits in reducing static stresses and improving the buckling load for shear-dominated loading cases [1], highlighting the importance of gathering understanding through design optimization. The inherent geometrical complexity of curvilinearly stiffened panels may render finite element analyses not adequate for this scope, and possible issues due to element distortion and skin-stringer continuity enforcement have to be taken into account. These aspects, in conjunction with the computational time for performing sensitivity studies and design optimization, suggest the development of novel mesh-free, fast design tools to be used for rapidly generating the models, and assessing the structural response in a reduced amount of time. This work illustrates a formulation based on the method of Ritz, where stiffened panels are described as the assembly of plate and beam elements for modeling the skin and the stringers, respectively. Specifically, thin plate theory is adopted along with first-order beam theory. The stringer path is parametrized using quadratic and cubic Bézier curves, which allow for a straightforward definition of the path as function of few control points. Compatibility at the interface is specified in exact form and using penalty functions. The approach is developed in the framework of a displacement-based formulation, where the generalized displacement components

are expanded by means of Legendre polynomials due to their excellent convergence properties [2-4]. Relatively high number of trial functions, which can be necessary for capturing local modes, are easily handled thanks to the efficiency of the implementation. The linear static response is analyzed, with focus on pre-buckling and buckling behaviour. The quality of the results is assessed by comparison against finite element calculations, illustrating the potentialities of the proposed tool as a valuable mean for performing preliminary parametric studies and assessing the potential benefits of panels with curvilinear stringers. References [1] S.P. Gurav and R.K. Kapania. Development of framework for the design optimization of unitized struc- tures. In 50 th AIAA/ASME/SAE Structures, Structural Dynamics and Materials Conference, AIAA 2009-2186, Palm Springs, CA, May 4-7 2009. [2] Z. Wu, P.M. Weaver, G. Raju, and B.C. Kim. Buckling analysis and optimisation of variable angle tow composite plates. Thin-Walled Structures, 60:163-172, 2012. [3] A. Milazzo and V. Oliveri. Post-buckling analysis of cracked multilayered composite plates by pb-2 Rayleigh-Ritz method. Composite Structures, 132:75-86, 2015. [4] R. Vescovini, L. Dozio, M. D'Ottavio, and O. Polit. On the application of the Ritz method to free vibration and buckling analysis of highly anisotropic plates. Composite Structures, 192:460-474, 2018.

Response of moderately thick arbitrary laminates to transverse forces

abst. 15703
Room 1
Wednesday
July 3
09h20

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Shear moduli of advanced unidirectional composite materials can be lower than Youngs' moduli along the fiber direction by almost two orders of magnitude. Therefore, the influence on transverse shear strain on plate deformation can be much more significant in laminates than in homogeneous plates made from isotropic materials. The modeling of shear behavior in laminates, and particular in sandwich plates, has received much research attention. The here presented exact solution maps the shear response of a general laminate in the sense of a point model rather than a structural model. The model assumes homogeneous transverse cutting forces, or cylindrical bending with linearly increasing bending curvatures, respectively. It combines macro deformations from plate theory with spatial displacement fields where the latter are solved by exactly satisfying all conditions and relations of linear elasticity. The model maps warping functions as well as shear stresses and strains for arbitrary laminate design. Only for calculating the plate-shear-stiffness matrix, an energy argument needs to be employed. For homogeneous laminates, the predicted plate-shear-stiffness corresponds with Timoshenko's suggestion of a shear-correction factor 5/6 in his theory. The exact model is verified by comparison with other theories or numerical simulations, respectively.

Modelling thick composites laminates exposed to hygrothermal environment based on high order shear deformation using polynomial functions.

abst. 15711
Room 1
Tuesday
July 2
12h50

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Static characteristic of thick composites laminates exposed to hygrothermal environment are studied within the framework of high shear order deformation theories. The displacement field takes into account the thickness stretching effect (Zenkour et al., 2007). Following the suggestion of Mguyen (2016), a quintic polynomial function is adopted f(z) to represents the nonlinear distribution of the transverse shear strains and stresses through the thickness. Considering the normal through-the thickness strain is important even in thin laminates (Cantera et al., 2015) The polynomial f(z) is a simple and unified formulation that represents all existing transverse shear function, and and its derivative covered the derivatives , that have a the parabolic-type shape, of various transverse shear functions proposed. The modelling is based on the Rayleigh-Ritz technique and the unknown values of coefficients of the polynomials were determined by minimising the Total Potential Energy of the laminate. The normal and shear strain modelling is extended in the present work by considering: - the initial hygrothermal residual strains due to temperature and moisture increments, - Nonlinear terms of the out of plane displacement