Many cylinders were found to have a KDF 20 to 30% higher than a QI cylinder. It was found that, in general, the fewer the number times the lamina was sheared, the higher the KDF. However, it was found that the higher the number of stiffening elements, the higher the specific, imperfect buckling load. The stiffening elements did not act as panel breakers as the EI contribution was not large enough, instead acting as load attractors. Layups that used the maximum amount (70 degrees) of shearing had a lower KDF when compared to a layup that used a medium degree (30 – 40 degrees) of shearing. The cylinders that had the highest KDF had a localised buckling mode, indicating that the shearing had caused a trapping of the buckling mode. The cylinders that had the lowest KDF had a global buckling mode. It was found that there is a relationship between the difference in pre-buckling strain field (between a perfect and imperfect cylinder) and the knockdown factor. This novel relationship is strong when the KDF is high, showing that a linear analysis can provide a first-order approximation of the imperfection sensitivity of a cylinder.

Physics-Informed Neural Networks for the Analysis of Composite Structures

abst. 2573
Virtual Room
Tuesday
September 1
14h30

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The growing use of composite materials and the increasing complexity of modern composite structures - see, e.g., variable-stiffness (VS) configurations [1] - make advanced analysis tools more and more important. In this context, different methods [2-4] have been proposed to effectively analyze the mechanical response of VS composite structures. In the present work, a new method is presented for the analysis of VS configurations based on Artificial Neural Networks (ANNs). Due to their universal approximation properties, ANNs have been widely used as metamodels for design and analysis purposes. However, standard NN architectures are commonly used as a 'black-box', where training relies solely on the set of available data and without considering the intrinsic physics of the problem. One crucial aspect is the amount of data to train the network, which, in many practical problems, can be scarce as resulting from costly analysis or experiments. Recent advances in machine learning have introduced a new class of ANNs, known as Physics-Informed Neural Networks (PINN) [5]. In this new kind of neural networks, the information content of available training data is enriched by considering a physics-based loss function, which embeds the underlying physics of the problem. This knowledge is not exploited in conventional ANNs. In this work, presented is an application of PINNs for the analysis of advanced composite structures with emphasis on static elasticity problems. Results are generated by training PINNs with Gradient-Based Learning (GBL) algorithms. Among the different optimization techniques available in literature, the Adam optimization rule [6] is used here. Results show that PINNs can predict accurately the solution, even when trained with limited and noisy data. A second strategy, alternative to GBL algorithms, is proposed in the present work. The approach refers to the so-called Extreme Learning Machine (ELM) [7]. Differently from GBL, where all parameters of the network are tuned iteratively, only the outer layers weights are trained in ELM; the inner parameters are chosen randomly. The comparison with GBL shows that even better generalization performance, at a much lower training time, is obtained for ELM. Although the following results are still preliminary, the proposed framework is promising and can be applied for solving a wide range of problems ranging from structural analysis to optimization problems. Acknowledgments: The research leading to these results has been funded by Ministero dell'Istruzione, dell'Università e della Ricerca, PRIN 2017. References [1] Z. Gurdal, R. Olmedo. Composite laminates with spatially varying fiber orientations: Variable stiffness panel concept. Structural Dynamics and Materials Conference, 2472, 1992. [2] R. Vescovini, L. Dozio. A Variable-kinematic model for variable stiffness plates: vibration and buckling analysis. Composite Structures, 142, pp. 15-26, 2016. [3] G. Raju, Z. Wu, P.M. Weaver. Postbuckling analysis of variable angle tow plates using differential quadrature method. Composite Structures, 106, pp. 74-84, 2013. [4] P. Ribeiro, H. Akhavan. Non-linear vibrations of variable stiffness composite laminated plates. Composite Structures, 94(8), pp. 2424-2432, 2012. [5] M. Raissi, P. Perdikaris, G.E. Karniadakis. Physics-informed neural networks: A deep learning framework for solving forward and inverse problems involving nonlinear partial differential equations. Journal of Computational Physics, 378, pp. 686-707, 2019. [6] D.P. Kingma, J.L. Ba. Adam: a method for stochastic optimization. International Conference on Learning Representations, pp. 1-13, 2015. [7] G.B. Huang, Q.Y. Zhu, C.K. Siew. Extreme learning machine: theory and applications. Neurocomputing, 70(1-3), 489-501, 2006.

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abst. 2554
Virtual Room
Tuesday
September 1
14h15

A 3D SHELL MODEL FOR THE THERMAL AND HYGROSCOPIC STRESS ANALYSIS OF COMPOSITE AND SANDWICH STRUCTURES

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A general 3D exact shell solution for the thermo-hygro-elastic analysis of a heterogeneous group of multi-layered composite and sandwich structures is proposed. The 3D equilibrium equations are written in orthogonal mixed curvilinear coordinates, they are valid for spherical shells and they automatically degenerate in those for simpler geometries. The elastic part of the proposed model is based on a layer-wise exact solution where the exponential matrix method allows to solve the differential equations through the thickness direction. Simply-supported boundary conditions and harmonic forms for each variable are employed. The temperature and moisture content amplitudes are imposed at the external surfaces in steady-state conditions. Therefore, the related profiles can be evaluated through the thickness direction in three different ways: - calculation of temperature and moisture content profiles using 3D Fourier heat conduction and 3D Fick diffusion equations, respectively; - evaluation of temperature and moisture content profiles using 1D version of Fourier heat conduction and Fick diffusion equations, respectively; - a priori assumed linear temperature and moisture content profiles through the thickness direction. After the definition of the temperature and moisture content profiles, they can be considered as known terms in the 3D differential equilibrium equations. A set of non-homogeneous second order differential equilibrium equations are obtained. After a reduction to a first order differential equation system, the exponential matrix method is used for both the general and the particular solutions. The effects of the temperature and moisture content fields on the static response of plates and shells are investigated for different thickness ratios, geometries, lamination schemes, materials and temperature/moisture content values. Results will demonstrate the importance in the 3D shell model of both the correct definition of the elastic part and the appropriate evaluation of the temperature and moisture content profiles through the thickness of the structures.

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abst. 2641
Repository

Compressive proprieties of different nanoparticles reinforced epikote 828 nanocomposite (CB/epoxy , CNT/epoxy , GNP/epoxy nanocomposite)

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The effect of adding several nanoparticles as carbon nanotube CNT, carbon black CB and graphene GNP on the compressive proprieties of Epikote 828 epoxy was studied. A series of epoxy-based nanocomposite with 1-4wt% CNT, 1-5 wt% GNP and 1-2 wt% CB was prepared. static uniaxial compression tests were conducted to study the effect of CNT, CB and GNP on the compressive stress-strain behavior of the Epikote 828 polymer. It's as found that the compressive proprieties depend on the nature, mass fraction of nanoparticles reinforcement and its interaction with the epoxy. Reduction in compressive strength for 4wt% CNT and 5wt% GNP were recorded, which due to the intercalated structure way and the high density of CNT, GNP addition in the polymer that creates in its turn a high localized stress in the matrix during compression that leads to premature failure. However, adding carbon black shows enhancement in the compressive mechanical performance of the epoxy even with high mass fraction it didn't present a decrease in the strength structure which confirm the good interaction with matrix epoxy.
