monitoring is a very hot topic today. This also applies to recently developed self-healing thermoplastic composites [1] in order to evaluate their healing effectiveness. Because internal defects affect the structure surface strain field, measuring surface strains it is possible to predict existing internal defects. Digital Image Correlation (DIC) method, as a non-contact full field displacement and strain measurement technique, gained popularity during these decades and can be used for such purposes [2]. Because DIC strains are calculated from displacement by applying numerical differentiation of the DIC displacement field, measurement noise is exaggerated, causing not existing strain peaks. On the other hand, when filtering strain peaks, it is possible that material defects can be filtered out too. Peridynamics theory based on the integral continuum mechanics formulation offers the peridynamic differential operator (PDDO) [3] to find the derivative of displacement only using integrals. Thus, both high strain spatial resolution and low noise can be achieved. In this study 3D DIC system is applied to identify defects in self-healing glass fiber composite (to measure surface strains), and PDDO is used for strain post-processing to increase the defect detection accuracy. Finite element updating (FEMU) method, comparing simulated and experimental strain fields, is applied to define the defect shape and position (e.g., depth in the structure). Finally, to prevent the not unique defect shape and depth prediction found by FEMU and to validate the proposed method, X-ray tomography is used. References: 1 Khan, T.; Irfan, M.S.; Cantwell, W.J.; Umer, R. Crack Healing in Infusible Thermoplastic Composite Laminates. Compos. Part A Appl. Sci. Manuf., 2022, 156, 106896. doi: 10.1016/j.compositesa.2022.106896. 2 Correlated Solutions. DIC system https://www.correlatedsolutions.com/digital-image-correlation/ (accessed Feb 4, 2022). 3 Madenci, E.; Barut, A.; Dorduncu, M. Peridynamic Differential Operator for Numerical Analysis; Springer International Publishing: Cham, 2019.

Experimental testing and numerical modelling of impacts in interpenetrated composite

abst. 1010
Room A
Thursday
September 21
16h00

Postek, Eligiusz (ewpostek@googlemail.com), Institute of Fundamnetal Technologicla Research PAS, Warsaw, Poland
Pietras, Daniel (pietras140t@gmail.com), Lublin University of Technology, Poland
Guhathakurta, J. (guhathakurta@ct-lab-stuttgart.de), CT-LAB Stuttgart, Germany
Kruszka, Leopold (), Military University of Technology, Warsaw, Poland
Grążka, Michał (), Military University of Technology, Poland
Sadowski, Tomasz (t.sadowski@pollub.pl), Lublin University of Technology, Poland

The interpenetrating composites consist of a scaffold and metallic matrix, which fills it being introduced under pressure. The scaffold is usually crushable. In our case, the SiC material stands for the skeleton, while the AlSi12 alloy is the matrix. Both materials are crushable. The SiC phase is brittle throughout the loading process, but the AlSi12 alloy is brittle during the elastic phase; then, its behaviour becomes viscous-plastic. The presentation concerns the experimental testing and simulations of the impact and fragmentation of metal matrix composite - AlSi12/SiC. The numerical model of the internal structure is created based on CT scanning. The microstructure of the composite is complex and consists of a metallic phase (85%), ceramic SiC skeleton, porosity, and a system of not perfect interfaces. The impacts are realized in the following few scenarios. The exemplary scenario is realized by imposing the initial conditions on the sample that hits a hard elastic barrier. The second one corresponds to SHPB experiments. The last one is the hitting of an elastic impactor against the sample. The influence of the impact velocities and material parameters of the phases on the failure modes is observed. Previously, analyses of the modes of loading application on the micromechanical failure of metal matrix composite were analysed in [1, 2]. An analysis of the empty SiC scaffolds is presented in [3]. The proposed finite element model of the AlSi12/SiC composite behaviour describing gradual degradation under impact loading was tested for different scenarios of hitting. In all cases, the growth of damage in the composite is very realistic. These results lead to the conclusion the proposed finite element model is very effective. Acknowledgement: The results presented in this paper were obtained within the framework of research grant No. 2019/33/B/ST8/01263 financed by the National Science Centre, Poland. The numerical analyses were done in the ICM UW in Warsaw and in CI TASK in Gdańsk, Poland. References: [1] Postek, E. and Sadowski, T. Distributed microcracking process of WC/Co cermet under dynamic impulse compressive loading. Compos. Struct. (2018) 194: 494-508. [2]

Postek, E. and Sadowski, T. Qualitative comparison of dynamic compressive pressure load and impact of WC/Co composite. Int. J. Refract. Hard. Met. (2018) 77: 68-81. [3] Postek, E., Sadowski, T. and Bieniaś, J. Simulation of impact and fragmentation of SiC skeleton, Phys. Letters (2021) 24:578-587.

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abst. 1017
Room A
Friday
September 22
14h45

Prediction of Critical Buckling Load on Open Cross-Section Columns of flax/PLA Green Composites

Wang, Liu J. (lwang@pa.uc3m.es), UC3M, Spain
Puerta-Hueso, Sergio (spuerta@pa.uc3m.es), UC3M, Spain
Pedroche, David (dapedroc@ing.uc3m.es), UC3M, Spain
Santiuste, Carlos (csantius@ing.uc3m.es), UC3M, Spain

In recent years, research into new biodegradable materials, such as natural fibers and bioplastics, has experienced a remarkable expansion thanks to the increasing use of natural resources in industries to replace conventional composites. They are recyclable, lighter, and cost-effective. Nevertheless, the mechanical behavior of green composites presents nonlinear elasticity, viscous effects, and plastic behavior before failure. These features make them harder to define by linear equations. Therefore, unconventional constitutive models are required. Between the nonlinear elastic theories, the modified Ludwick constitutive law was proved effective in characterizing the tensile response of flax fiber-reinforced biopolymer composite, and this law was experimentally validated for the first time in predicting the mechanical behavior of flax fiber-reinforced PLA composite in nonlinear buckling problem (Jiao-Wang et al., 2023). In the previous study (Jiao-Wang et al., 2023), the analytical formulation and the FEM numerical model were demonstrated to be effective in predicting the critical buckling load of slender close-section columns. As a continuation of the previous work, this study aims to find the validity limits of the modified Ludwick law to predict the critical buckling load of nonlinear elastic columns. Besides, this study hypothesizes that the modified Ludwick law can be used in an analytical model to estimate the nonlinear elastic behavior of green composites. The Euler theory is only valid to define the critical buckling load for slender columns, and the buckling modes cannot be predicted using a beam theory in columns with a lower slenderness ratio. Therefore, three different geometries (C-section 180°, C-section 90°, and C-section 60°) are chosen to manufacture open-section columns with slenderness ratios between 48.89 and 382.66. The analysis combines theoretical formulation, numerical modeling, and experimental tests. The validity of the analytical formulation based on the modified Ludwick's law and the FEM numerical model using the Marlow hyperelastic model is verified by comparing them with the experimental results. Woven flax fiber and PLA are the components used to make the fully biodegradable composite material. The manufacturing process is by hand laid up, stacking four layers of flax fabric with five layers of PLA film, and then compressed by heated plates (Jiao-Wang et al., 2023). Finally, the compressed flax/PLA plate is removed from the machine and quickly placed into the metal C-section molds. The analytical formulation based on the modified Ludwick law to compute the critical buckling load of flax/PLA columns was defined in the previous work. However, it is modified to apply for columns with open-section. Regarding the FEM numerical model, the biocomposite specimens are modeled in Abaqus/Standard as a solid deformable body and assimilated as an elastomeric material. They obey the isotropic Marlow hyperelastic material model, and the experimental uniaxial tensile data are provided as the input for the system. The boundary conditions were pinned–pinned to reproduce the experimental setup where the cross-section rotation was not restricted. Finally, the comparative analysis showed that the numerical model could reproduce the buckling behavior of the three cases. However, the errors of the critical buckling load prediction for the C90 and C180 columns were higher than for the C60 columns. Moreover, the theoretical estimations indicated that the C90 cross-section column was near the limit of application of the modified Ludwick law to predict the critical buckling load of nonlinear elastic columns with open cross-sections, and the C180 column was out of the prediction limits. Generally, the numerical and theoretical models underestimated the scattering effects of the predictions because the models did not consider all the experimental variables.
