CERIS Civil Engineering Research and Innovation for Sustainability

Thermo-mechanical structural modelling of FRP profiles subject to fire

Summary

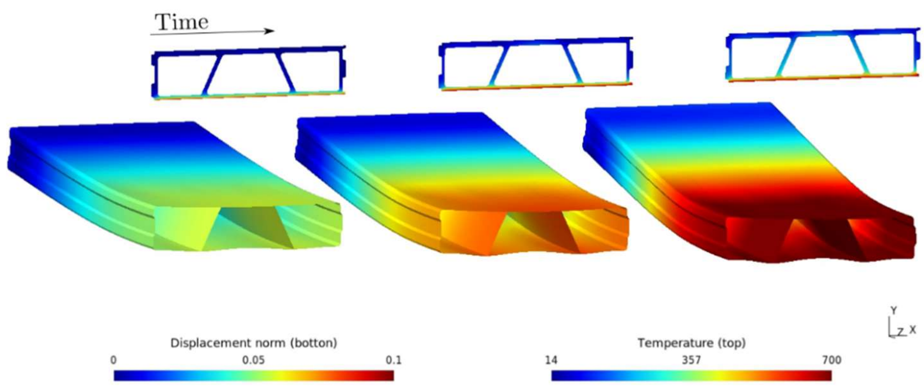
Fiber-reinforced polymers (FRP’s) are a wide class of composite materials consisting of a polymeric matrix reinforced with fibers. Due to their remarkable properties and relative low cost, these materials can nowadays be found in most engineering fields, with well established applications in the naval, aerospace and automotive industries. This success, however, did not carry over to the building construction sector, where, due to an overall poor fire performance, the use of FRP composites remains significantly limited. With the objective of further extending the application range of such materials, a new thermos-mechanical model is proposed for the simulation of FRP profiles subjected to fire. Aiming to reduce the overall computational cost associated with theproblem, the modelling process is sub-divided into two main parts. First, the thermal problem is independently solved for two-dimensional profile sections, in order to obtain the component’s temperature distribution. Hereafter, the obtained temperature data is used as input to the mechanical problem in a one-way couplingstrategy.

Considering the general thin-walled nature of the profiles in question, a new geometrically exact shell theory, simultaneously including thickness variations and initially curved geometries, is proposed for the problem’s structural model. While the initially curved feature facilitates the representation of more complex geometries, thickness variations allow the use of full three-dimensional constitutive relations, avoiding the enforcement of the plane-stress assumption (which is non-linear and computationally demanding). Profiting from the latter feature, a new three-dimensional material model, based on an existent anisotropic viscoelastic theory, is also proposed for FRP composites under extreme temperatures. This is set to take into account: (i) finite strains, (ii)viscoelastic behaviour arising from both fiber and matrix materials and (iii) anisotropic degradation of mechanical properties with the increasing temperatures.

The proposed shell model was implemented in a nin-house Fortran code in the context of the finite element method. Its corresponding constitute relation subroutines are directly interfaced with Matlib (a general C++ constitute model library) where the proposed material model was fully implemented. Both implementations were verified using benchmark examples found in the literature. The complete thermo-mechanical model was finally assessed by attempting to reproduce fire resistance experiments carried out at the IST-Lisbon for a commercially available GFRP profile. While the thermal part showed good agreement with the measured data, the mechanical part presented modest overall agreement, which the author mainly attributes to an insufficient material characterization of the experimented profile. Nevertheless, the proposed model is verified and, given a more complete material characterization, it can be used to broaden the overall knowledge on FRP composite materials under fire exposure.

Keywords

Multi-physics, non-linear finite elements, pultruded FRP composites, geometrically exact shell models, anisotropic finite viscoelasticity, fire behaviour.



Mechanical model results for three distinct time instants.

PhD student
Bruno Aguirre Tessaro

PhD program
Computational Engineering (IST, University of Lisbon and École Centrale Nantes)

Supervisor
Carlos Tiago (CERIS, IST, University of Lisbon)

Co-supervisors
Laurent-Stainier (École Centrale Nantes) and João Ramôa Correia (CERIS, IST, University of Lisbon)

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