

# A Rate Dependent Constitutive Model for Carbon-Fibre/Epoxy-Matrix Woven Fabrics Submitted to Dynamic Loadings

S. Marguet\*, P. Rozycki†, L. Gornet†

\*Ecole Centrale de Nantes, GeM, UMR CNRS 6183  
1 rue de la No BP92101, 44321 Nantes Cedex 3, France  
steven.marguet@ec-nantes.fr

†Ecole Centrale de Nantes, GeM, UMR CNRS 6183  
1 rue de la No BP92101, 44321 Nantes Cedex 3, France  
patrick.rozycki@ec-nantes.fr, laurent.gornet@ec-nantes.fr

## ABSTRACT

This paper deals with the modelling until rupture of composite structures made of carbon/epoxy woven fabrics and submitted to dynamic loadings.

The mechanical behaviour of the woven ply appears to be orthotropic, strongly non linear and rate dependent. In the warp and fill directions the ply behaves in a way slightly non linear, elastic and brittle whereas in shear, it can be observed a progressive loss of rigidity of the elastic modulus combined with inelastic strains. In this work, and in order to take into account the previous physical phenomena, we have adapted and strongly coupled a viscoplastic model with a delayed damage mesomodel [1]. In each direction of fibres, a damage variable drives the failure. In shear, the association of a damage variable with a plastic strain allows the model to represent the non linear irreversible effects described above. Special attention is paid to ensure a good representativeness of the model compared with the experiments on a large range of strain rates. This results in the introduction of viscous elastic moduli. The constitutive equations are solved implicitly throughout a backward Euler scheme which is implemented by the mean of a Closest Point Projector algorithm. To identify the parameters, an optimization procedure based on the direct search method is carried out. It leads to an accurate behaviour of the model in both tensile and shear directions for strain rates evolving from at least  $1.10^{-3} s^{-1}$  to  $1.10^3 s^{-1}$ .

Furthermore, to check the ability of the model to avoid strain localization phenomenon or mesh dependency, a campaign of simulations is performed on the classical example of a bar in tension. Finally, and in order to test the model on structural applications, both the impact on composite plate and the dynamic crushing of thin-walled tube are simulated and compared with some experimental results from [2] and [3]. The model developed in this study appears to be able to predict quite precisely the collapse of the structures from the initiation of a macroscopic cracks towards the rupture.

## References

- [1] P. Ladevèze, O. Allix, J-F. Deü, D. Lévêque, A mesomodel for localization and damage computation in laminates, *Computer Methods in Applied Mechanics Engineering*, Vol 183, pp 105-122, 2000.
- [2] A.F. Johnson, A.K. Pickett and P. Rozycki, Computational methods for predicting damage in composite structures, *Composites Science and Technology*, Vol 61, pp 2183-2192, 2001.
- [3] A.G. Mamalis, D.E. Manolakos, M.B. Ioannidis, D.P. Papapostolou, On the response of thin-walled CFRP composite tubular components subjected to static and dynamic axial compressive loadings: experimental, *Composite Structures*, Vol 69, pp 407-420, 2005.