Strain rate dependency of materials: characterisation and identification of models parameters. From standard procedure to advanced inverse methods based on full field measurements

B. Langrand[1a], T. Fourest[1] and J. Berthe[1]

[1]Onéra, French Aerospace Research Center,
Department Materials and Structures, F-59014 Lille Cedex, France
[a]bertrand.langrand@onera.fr

Abstract

The characterisation of material properties is very challenging especially when the number of material parameters governing the constitutive equations is significant. This is particularly true when considering anisotropic materials and/or strongly nonlinear constitutive laws, for example, in viscoplasticity or damage theories. Different normalized tests are necessary to fix the parameters of the material models. They are generally exploited based on statically determined approach, i.e. by assuming that the mechanical fields are homogeneous over the specimen gauge length (e.g., case of uniaxial tension). Material parameters are obtained with those tests in one loading direction while constitutive equations involve all strain and stress tensors components. Anyway, tests exploitation is limited to small levels of strain before plastic strain localisation. Consequently, a large number of tests are required when complex behaviours have to be characterised. For example, many tests have to be performed at constant strain-rate to identify viscoplastic models and/or at different stress triaxiality ratio and Lode angles for damage or failure models.

The limitations of the statically determined approach can be bypassed with the statically undetermined approach that considers no hypothesis on homogeneity of mechanical fields and therefore no constraint on loading conditions and test exploitation. The most widespread statically undetermined approach is the Finite Element Model Updating (FEMU) method. FE simulations are iterated until constitutive parameters leading to the best match between numerical computations and experimental measurements are found. Many FEMU methods do not require strain field measurements but other approaches have been developed to take advantage of their treatment. The Virtual Field Method (VFM), another statically undetermined approach, is based on the principle of virtual work that expresses the global equilibrium of a solid of any shape. The VFM enables to take the full advantages of full-field measurement techniques, such the Digital Image Correlation method. One of the main advantages of the VFM compared to FEMU methods is that it does not require building a numerical model of the test, including the boundary conditions.

The lecture aims at providing a synthesis of the research activities performed at Onera in the field of the materials characterisation under dynamic loadings (i.e., from 10^{-3}/s to 10^{+3}/s for structural crashworthiness and impact applications) and the parameters identification of constitutive behaviour and damage models. The presentation will focus on the different numerical methods available to identify/optimise the parameters of the material viscoplastic and damage models. The limitations of the normalised direct approach will be discussed. The presentation will introduce and develop other numerical approaches, based on inverse problem resolution techniques: the well-known Finite Element Model Updating method (FEMU) and the most advanced one based on the Virtual Fields Method (VFM). Applications for different materials and models will be given to support these advanced methods.