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A GLOBAL APPROACH TO THE FAILURE PREDICTION OF A RIVETED ASSEMBLY

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Summary. *A multi-scale technique is used to take the strain/stress effects of a perforation in a sheet due to the riveting process into account in finite element by avoiding its modelling. The interesting results of this work have lead to the investigation of damage models to introduce them in the global finite element simulation.*

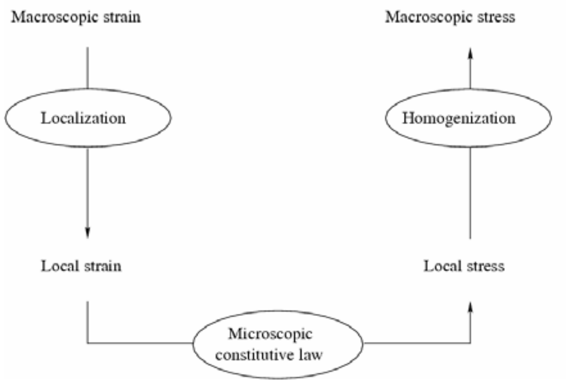
1 INTRODUCTION

Crash simulations with finite element codes have reached a high level of accuracy nowadays. Nevertheless, with the use of new materials such as aluminium and high strength steel, the occurrence of a failure in sheet or near a jointing assembly is a reality in crash situations. This failure could lead to dangerous strain kinematics for passengers. Consequently, a global approach to the failure of a riveted assembly is studied by first of all developing a strategy which takes the influence of the hole in the sheet into account and by introducing damage and failure models in finite element codes to numerically predict both the apparition of the failure and the way of its propagation in the structure.

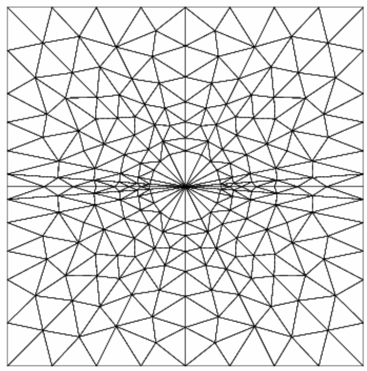
2 MULTISCALE MODELLING OF PERFORATED PLATE BEHAVIOUR

The hole is therefore not described in FE models although it greatly influences the mechanical behaviour of riveted airframes. The perforations lead to stress/strain concentrations which trigger and pilot the crack propagation in the plates. The effects of these perforations on the global ruin mode of the structure are called structural embrittlement and are characterised along the crack path by means of the ratio $\varepsilon/\varepsilon_\infty$, where ε, is the local strain and ε_∞ corresponds to the far field strain. Taking the embrittlement phenomenon into account is indeed fundamental to describe with accuracy the mechanical behaviour of aeronautical structures. The goal of this research is to find a methodology to capture the influence of the perforations at the structural scale.

This is undertaken using a multi-scale FE modelling concept using the Transformation Field Analysis approach [1]. With such an approach, the description of the perforation is no longer necessary at the structural scale and a mathematical formalism (Dvorak approach as localisation scheme) links the mechanical behaviour obtained at different scales. In such a case, the scale related to the perforation is called the meso-scale and macro-scale the one related to the aeronautical structure (figure 1). The TFA method is based on a Representative Volume Element (RVE) which describes the local geometry of the structure. This RVE is divided into a number of sub-volumes (figure 1) inside which the mechanical fields are assumed to be uniform. A sub-volume is thus a homogeneous part of the RVE. In the case of pure elasticity (figure 2), the microscopic mechanical fields are related to the macroscopic one by classical linear relations.



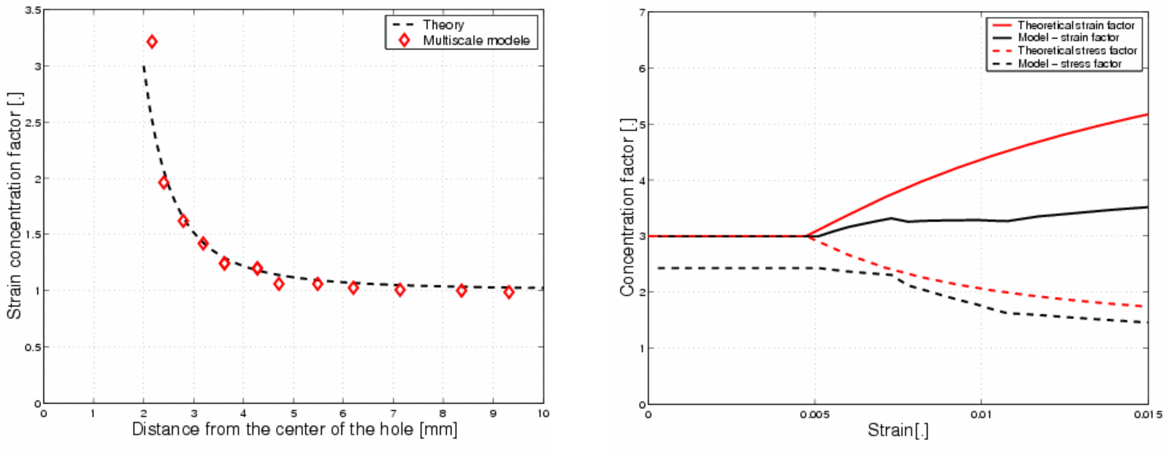
(a) Principle



(b) Representative Volume Element (RVE)

Figure 1 : Multiscale modelling.

When the behaviour is no longer elastic, additional terms must be added. Dvorak has considered non linearities due to plastic and/or thermal strains as eigenstrains. The local field is thus connected to the macroscopic ones. When the plastic strain is considered, the computation of the multi-scale model can no longer be done since a variable has been added although the additional equation is not considered. The multi-scale model is solved when introducing the tangent operators. The Euler scheme is used as a time integrator and the plastic strains are obtained [2]. The results expressed in terms of stress concentration factor seem to be quite close to theoretical ones. Nevertheless, when they are expressed in terms of the strain concentration factor, the results are not in good agreement with the theoretical ones (figure 2). The model seems to be too stiff and is not able to localize the strain enough. At the moment, several RVE meshes are used in order to assess the model.



(a) Elastic behaviour (b) Plastic behaviour

Figure 2 : Multiscale model results [2].

3 CONSTITUTIVE MODELS AND PARAMETERS IDENTIFICATION PROCEDURES

Clearly the more accurate the material models, the better the multi-scale embrittlement approach. The next steps therefore consist in introducing the enhanced damage-plasticity models in the numerical F.E. codes. For the damage part, experimental studies covering the range of plastic strain rates occurring in crash must then be performed to analyse the influence of the dynamic loading on the evolution of damage in sheets and near rivets. In this research, damage models introduced in an explicit finite element code are presented. The Gurson and Gologanu damage models are used and the shape and orientation of the microstructural cavities are taken into account in the finite element model developed so as to improve prediction of damage and fracture occurrence. The growth, nucleation and coalescence phases are considered to describe the evolution of the microvoid volume fraction. Lemaitre’s model is also used. The basic ingredient of the model is the damage law used in either monotonic loadings for the ductile fracture or in cyclic loadings for low cycle or high cycle loadings. This damage law depends on the strain energy density release rate which is the principal variable which governs the phenomenon of damage [3]. Experimental tests are then performed with a quasi-static test machine, servohydraulic test machine and Hopkinson bar on notched specimens for high strength steel (figure 3). An identification method based on an inverse technique is used. This method consists in the identification of the damage parameters by correlating, with an optimisation process, an experimental and numerical macroscopic measurement strongly dependent on the parameters [4]. Tensile tests of notched flat specimens with 2, 3 and 4 mm radii are used as experimental tests. The variation in the bottom of the notch in function of the elongation of the notched specimen and the variation of the axial force in function of the elongation of the notched specimen are used as a macroscopic measurement. Numerical simulations with all the damage models are then performed to compare with experimental results.

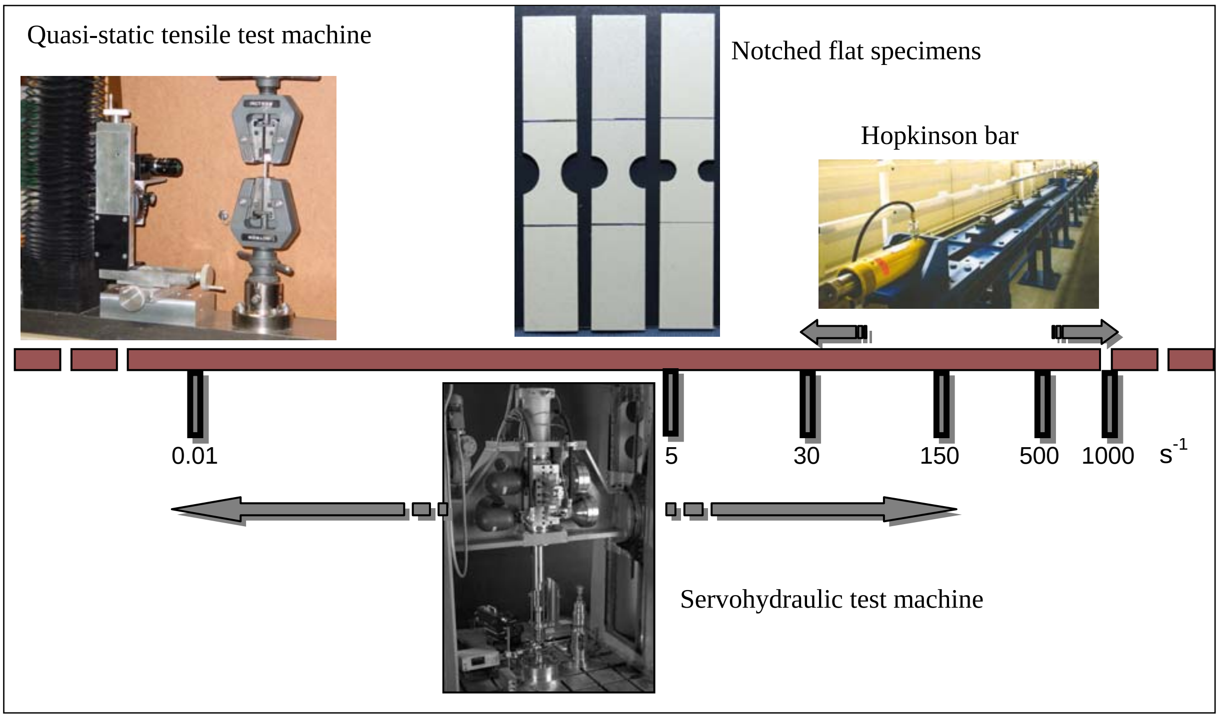


Figure 3 : Tensile tests for different plastic strain rates using quasi-static, servohydraulic and Hopkinson bar test machines.

4 CONCLUSIONS

The multi-scale technique has been applied to a perforation in the elastic and plastic strain fields. Damage models have been used on several materials in dynamic loadings. A new global approach to the failure prediction of a riveted assembly could be then totally investigated.

5. REFERENCES

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