

B04/3

DAMAGE OF DUCTILE PLASTIC MATERIALS IN NUCLEAR COMPONENTS: DEVELOPMENT OF AN INDUSTRIAL NUMERICAL TOOL

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1. INTRODUCTION

To study how harmful a defect in a structure can be (crack, ...), an analysis based on the concept of local approach is well suited. A rheological model has been implemented in the CASTEM 2000 finite element code, for elastoplastic materials with isotropic hardening and damage characteristics. The aim of this paper is to simulate, with the help of this numerical tool, a ductile rupture test on a notched specimen subject to tension.

2. GOVERNING EQUATIONS OF THE MODEL

The constitutive equations of the model [1] are derived from the classical elastoplastic theory coupled to a damage theory [2]. The damage variable rate D depends upon internal and associated variables, material parameters such as :

D_c : damage value above which a crack appears.

ϵ_R : deformation when a crack appears.

ϵ_D : deformation value below which D is = 0.

3. SAMPLE SPECIFICATIONS

The material tested is made of steel (A 508 CL3) and is homogeneous and isotropic (see stress strain curve on figure 1). The sample is axisymmetrical and notched at its mid-length. The finite element mesh is then reduced to a quarter of a longitudinal section (figure 2).

4. RESULTS AND DISCUSSION

The stress σ_{zz} at three Gauss points A, B, C is shown on figure 3. The sudden drop of curve A before that of curves B and C shows that the crack appears at the centre of the specimen, and propagates towards its external edge, a fact already observed experimentally on such notched samples. The critical imposed U_z displacement when the crack appears corresponds to the maximum of curve A ($U_z = 0,58$ mm). A being totally damaged, all the effort is transferred onto B. The experimental value is $U_z^{exp} \approx 0,525$ mm. Rousselier's model [3], in which the plastic strain induces a volume variation, leads to $U_z \approx 0,53$ mm.

The crack propagation can also be visualized on figure 4. The moment the crack reaches a Gauss point, a drastic change of slope of U_z appears. The calculated reaction force versus the diametral contraction fits well with the experimental curve (figure 5). Figure 6 shows, at various loads (termed as t), the evolution of the damage variable D . A D_{max} front reaches D_c (20 %) at the centre at $t \approx 0,592$. The tear then spreads towards the edge of the sample. The radial displacement of node P_r at $t \approx 0,592$ is $- 0,795$ mm, where as the experimental value is $- 0,8$ mm.

A sensitivity analysis of the model to D_c , ϵ_R , ϵ_D shows that, unlike ϵ_R , D_c and ϵ_D have an effect on the starting point of the crack.

The previous calculations are performed using the "large displacements" theory. Figure 7 shows the results using small displacements. Somehow, one other set of parameters ϵ_R , ϵ_D , D_c , gives a good prediction. But the ϵ_R value is certainly unrealistic (225 %) (figure 8) : it only shows the importance of the initial assumption associated to the model.

5. CONCLUSION

An elastoplastic law for materials with isotropic hardening and damage programmed in the CASTEM 2000 code allows a good description of a ductile rupture test on a notched sample. Somehow, an accurate experimental determination of the damage parameters is the key to the proper use of the model.

6. REFERENCES

- [1] C. STRUB - 1991 - "Introduction dans CASTEM 2000 d'un modèle de matériaux élastoplastiques à écrouissage et endommagement isotropes" - Rapport DMT/91-178 (internal report).
- [2] J. LEMAITRE - J.L. CHABOCHE - "Mécanique des matériaux solides".
- [3] G. MOTTET et al. - "Nouvelle possibilité numérique offerte par un modèle d'endommagement pour prédire l'amorçage et la propagation d'une fissure" - Rapport FRAMATOME - Action DTUD n° 001-2052 (FRAMATOME internal report).

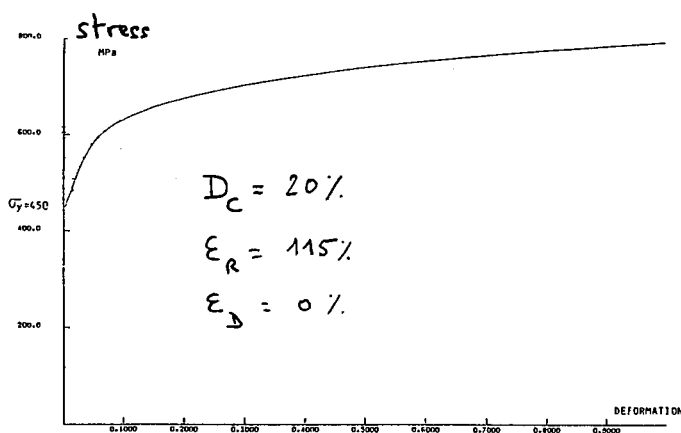
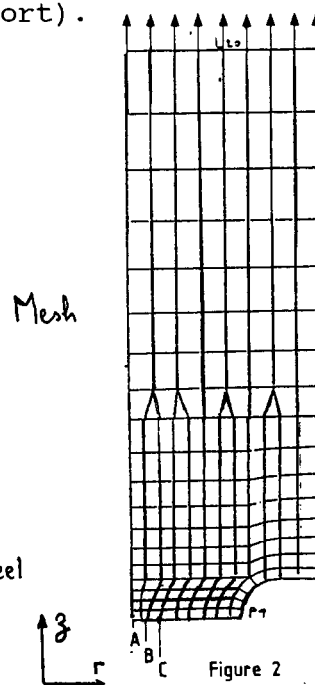


Figure 1.

Stress - Strain relationship of the A508 CL3 steel



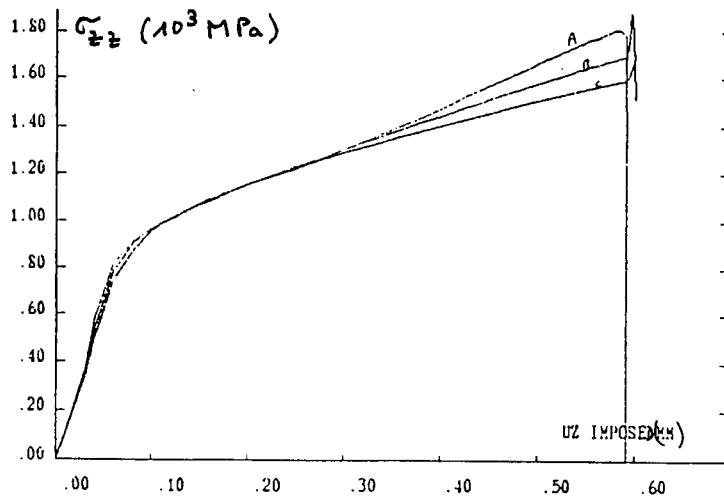


Figure 3

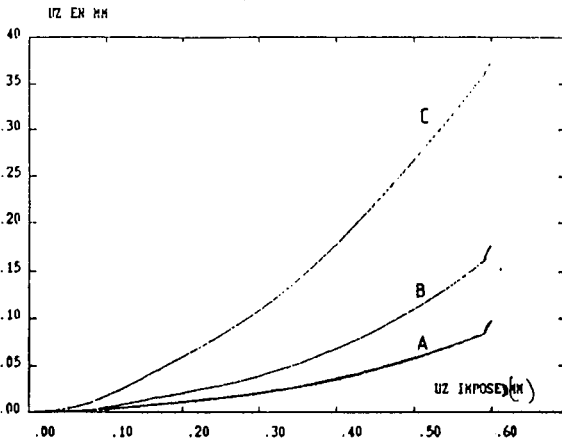


Figure 4

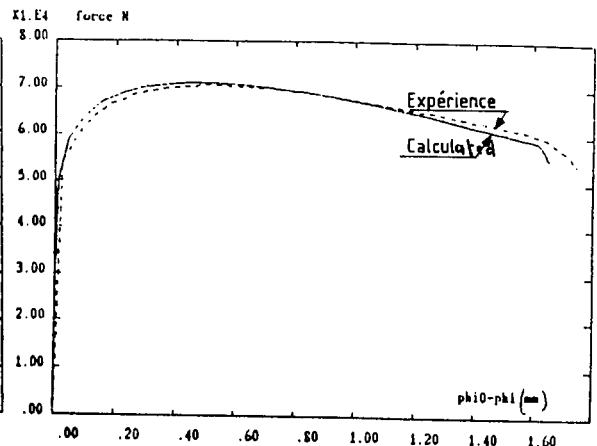
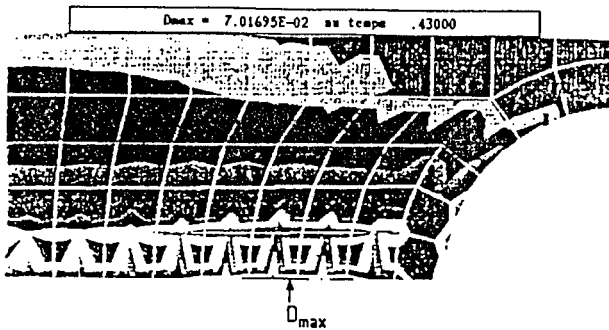
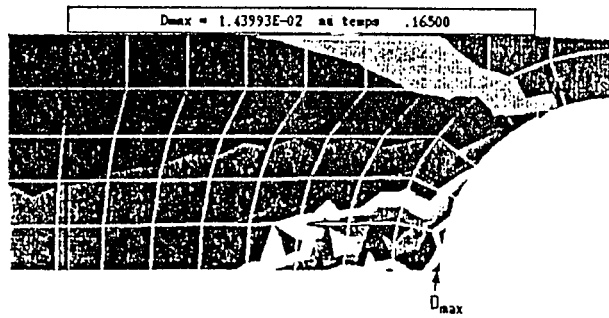


Figure 5

Figure 6
Isodamage D



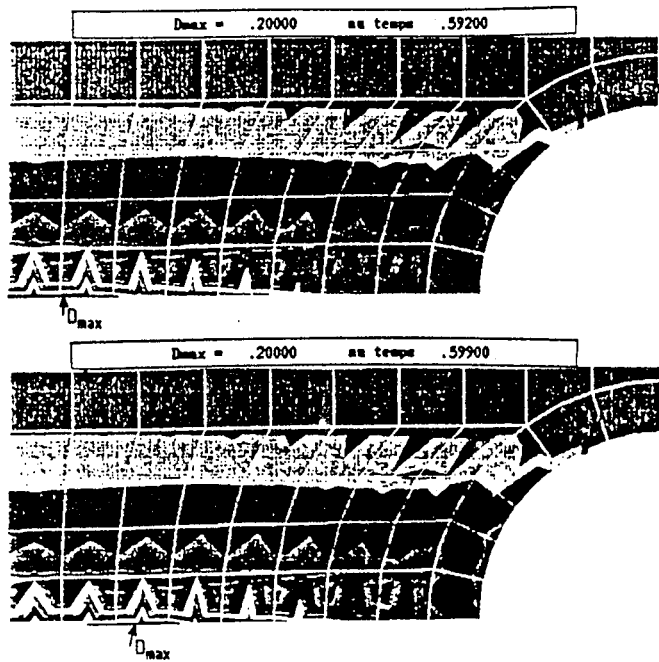


Figure 6

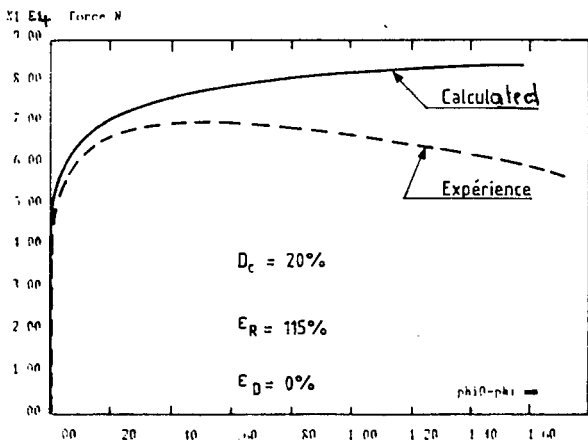


Figure 7

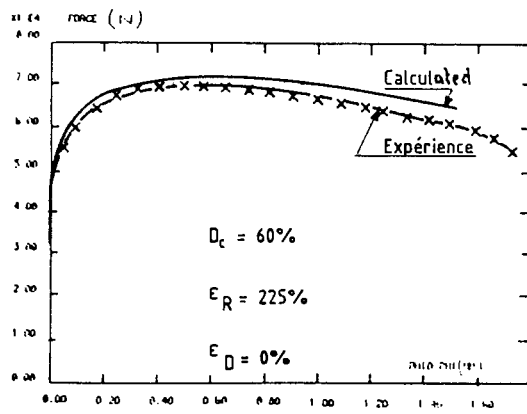


Figure 8

Small displacements

