THERMAL AND VOID VOLUME FRACTION PROFILES IN 3D FOR A DENT SPECIMEN OF NEAT AND GLASS OF SYNTACTIC POLYPROPYLENE MATERIALS

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Abstract

Glass of syntactic polypropylene (GsPP) is used for thermal insulation of subsea pipelines. This contribution displays the temperature and deformation fields in 3D on Double Edge Notched Tensile (DENT) specimens, made of both polypropylene (PP) matrix and GsPP. The influence of the microstructural and the thermal changes in the notched section on the load versus crack opening displacement curve is analyzed. The definition of the crack initiation in relation to a critical void volume fraction is discussed.

1. Introduction

In Fracture Mechanics approach [1], the fracture toughness is a global parameter corresponding to the energy release rate or the J-integral at crack initiation. For polymers, at the microscopic scale, the definition of this crack initiation might be problematic [2] since the evolution of the cavitation ahead of the crack tip seems to be a continuous phenomenon. In addition the thermal activities in the remaining ligament (notched section) experiencing a stress singularity is of interest [3]. An attempt is made here to relate the evolution of the void volume fraction near the crack tip as well as the temperature rise at the lateral surfaces to the load versus crack opening displacement (COD) curve for two grade of polyproplyene: neat polypropylene (named PP) and glass of syntactic polypropylene (GsPP). The glass reinforcement is composed of microsphere and the PP is supposed to be the matrix of the composite material GsPP.

To this end, Double Edge Notched Tensile (DENT) like specimens were machined using the two materials. The notch root radius of 0.15 mm was machined so as to better control its geometry but to mimic a natural crack. Tensile tests were carried out : i) at the laboratory where the load, the cross head displacement, video and infrared cameras records were produced ; ii) in-situ at synchrotron Soleil leading to the same data as before, combined with the microstructural evolution in 3D, synchronized with the actual load displacement curve.

Finite Element (FE) simulations of the SRT tests were used to better analyze the inference of the void growth to the shape of the load versus COD curve, for both PP matrix and GsPP.

2. Results

Figure 1 displays an overview of the experimental and the FE results:

a. Figs 1.a-b show the normalized load versus applied displacement during an in-situ test using Synchrotron Radiation Tomography (SRT). Open circle symbols represent the “time” where the scans were carried out. This allowed the examination of the microstructure gradual change within the notched section.
b. Figs 1.c-d illustrate the state of the microstructure ahead of the crack tip and at mid-thickness, before the maximum load was reached. It was observed that cavitation appeared as crazes for neat PP and as a combination of decohesion and crazes in the GsPP. The maximum cavitation was located at mid-thickness and near the crack tip.
c. Figs 1.e-f display for each material a contour map of the void volume fraction obtained by using Finite Element analysis, at the same moment of the SRT examinations corresponding respectively to Figs. c-d. The location of the maximum porosity is in excellent argument with the SRT observations.

d. The infrared camera results showed gradient of temperature rise. The maximum temperature rise measured at the surface was located at mid-thickness and ahead of the crack tip.

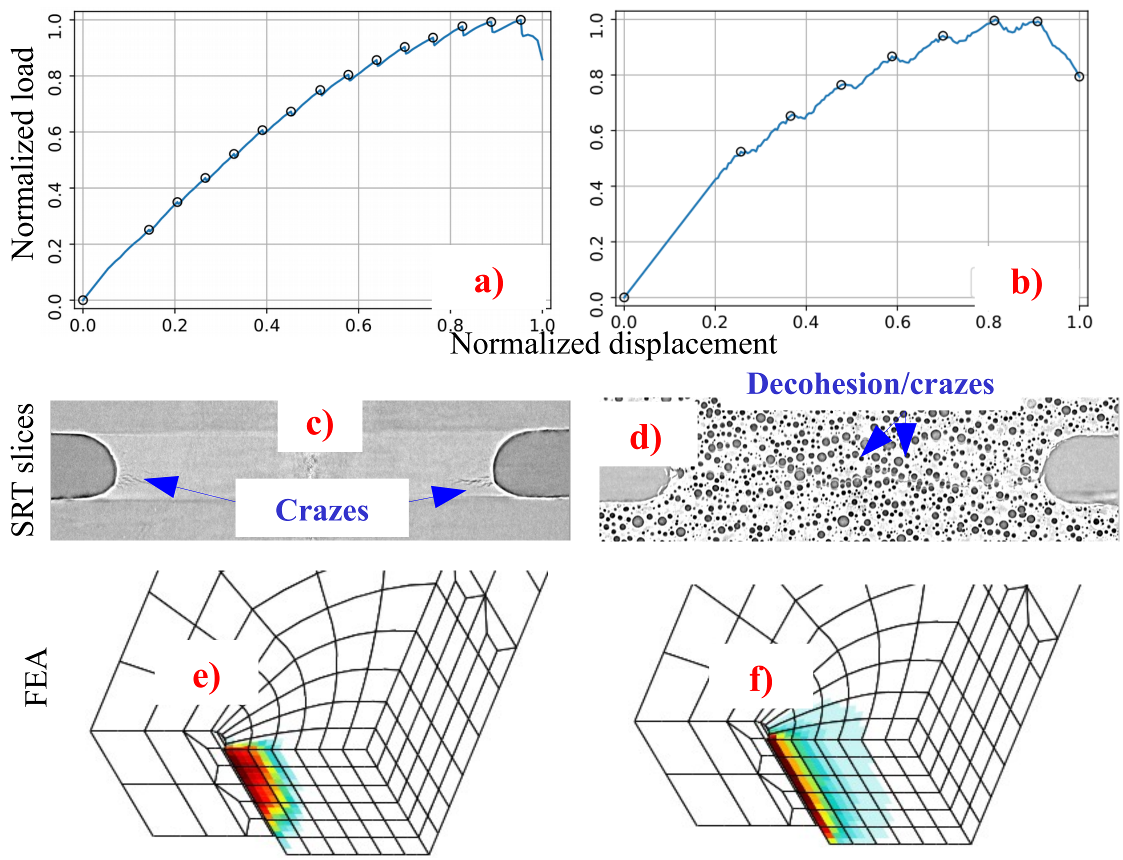

Fig.1 – Experimental and FE simulation results: left a), c), e) for neat PP ; right b), d), f) for GsPP

3. Conclusions

The combination of 3D imaging by SRT and FE analysis allowed a better understanding of how the gradual cavitation ahead of the crack tip modify the shape of load versus COD curve. The crack initiation concept could be related to a critical amount of porosity. The temperature rise at the lateral surfaces (width and thickness) was observed to follow the 3D stress field.

Bibliography

[1] F. Baldi, S. Agnelli, L. Andena, B. Blackman, L. Castellani, P. Frontini, J. Kucera, L. Laiarinandrasana, A. Pegoretti, A. Salazar and L. Warnet (2020) Determination of the Fracture Resistance of Ductile Polymers: The ESIS TC4 Recent Experience, Materials Performance and Characterization 9 (5), 675–687 . 10.1520/MPC20190175F.

[2] F. Baldi, S. Agnelli, T. Ricco, (2013) On the determination of the point of fracture initiation by the load separation criterion in J-testing of ductile polymers, Polymer Testing 32, 1326–1333. 10.1016/j.polymertesting.2013.08.007

[3] C. Ovalle, G. Boisot, L. Laiarinandrasana (2020), Effects of stress triaxiality ratio on the heat build-up of polyamide 11 under loading. *Mechanics of Materials*, 145, pp.103375. ⟨10.1016/j.mechmat.2020.103375⟩.