DUCTILE FAILURE OF A PLASTICIZED POLYVINYLCHLORIDE DURING AIR BAG DEPLOYMENT

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Abstract
The present work addresses the ductile fracture process of a plasticized Polyvinylchloride (PVC), constituting the skin of the dashboard, with the goal of ensuring the security of passengers for the automotive industry. Clamped single edge notch bending (SENB) specimens were used to characterize the mechanisms of crack initiation and propagation for the studied material. The ductile failure of the plasticized PVC, by using fracture mechanics tools, was characterized thanks to the exploitation of the experimental database associated with finite element simulation of the crack propagation.

1. Introduction

The correct deployment of airbag spreading is a major concern for the security of passengers in the automotive industry. The design and elaboration of the dashboard is one of the key features for obtaining the required specifications. Plasticized PVC skins are commonly used for the top surface of the three layers of the dashboard. Full scale tests have been carried out at various temperatures and a fixed impact speed of about 20 m/s (Fig. 1):

- At 23 °C (Fig. 1.a), a net ductile tearing of the skin, following the scoring direction and accompanied by the deformation of the top surface of the airbag box, was observed. This is the desired fracture process.
- At −35 °C (Fig. 1.b), a brittle failure of the skin occurred with small deformations. The main crack was on the surface plane, following the scoring direction; however, the presence of secondary transverse cracks was noticed. These may provoke fragmentation of the dashboard, accompanied by the projection of the pieces of the material.
- At 85 °C (Fig. 1.c), a significant deformation of the box together with an extreme extension of the skin delayed the opening time, if it occurred, as ballooning could prevent the opening of the box. This situation is the most dangerous condition which needs to be avoided even though the ultimate failure could also be qualified as ductile.

Full scale experiments are very costly; therefore, a research program was elaborated to directly test the plasticized PVC skin [1]. PVC skin plates were provided by the Westlake Global Compounds company. Scoring was added as a pre-crack on the samples using a robot for better reproducibility. As the desired failure mode is the ductile one, this constitutes a limitation for the use of Charpy tests. Indeed, the specimen may not fail after the impact. In this extreme case of no failure, the impact strength cannot be determined. Additionally, as mentioned above (test at 85 °C), this is the most dangerous situation. The aim of this work is then to characterize the ductile failure of the plasticized PVC by using fracture mechanics tools.

2. Results

Dedicated clamped SENB specimens were used to characterize the mechanisms of ductile crack initiation and propagation for the studied material. The crack initiation occurred before the maximum load prior to the final failure of the specimen. It was observed when the loss of linearity in the load versus COD appeared. Using a "release nodal degree of freedom" procedure, an in-house FE code allowed the simulation of the crack extension. The calibration factor of the clamped SENB specimen with respect to the crack depth ratio was established. The fracture toughness J_c , defined as the numerical J-integral at the crack initiation, was evaluated to be 10.8 kJ/m^2, in agreement with values in the literature. Besides, the corresponding impact strength for the initial drop tower tests [1] in the upper shelf was corrected. The modified fracture toughness and the impact strength values were proposed in the methodology allowing the ductile crack initiation to be predicted.

- For the drop tower test results, two methods were proposed [2]:
  - by running FE analysis of the test and selecting the time when the J-integral reached the value of 10.8 kJ/m^2, and
  - by detecting the loss of linearity in the load versus deflection curve for which the fractured surface energy density was equal to 0.11 kJ/m^2.
- For the dashboard where the plasticized PVC skin was integrated. FE simulation of the airbag display should be performed up to the time when the numerical J-integral reached the value of 10.8 kJ/m^2. Using FE code would allow the optimization of many parameters to lead to a safe deployment of the air bag.

Furthermore, lab-scale tests reproducing the boundary conditions of the airbag deployment were run at three temperatures (Fig. 1.d): [-25, 20, 85] °C. The experimental data will be also discussed.

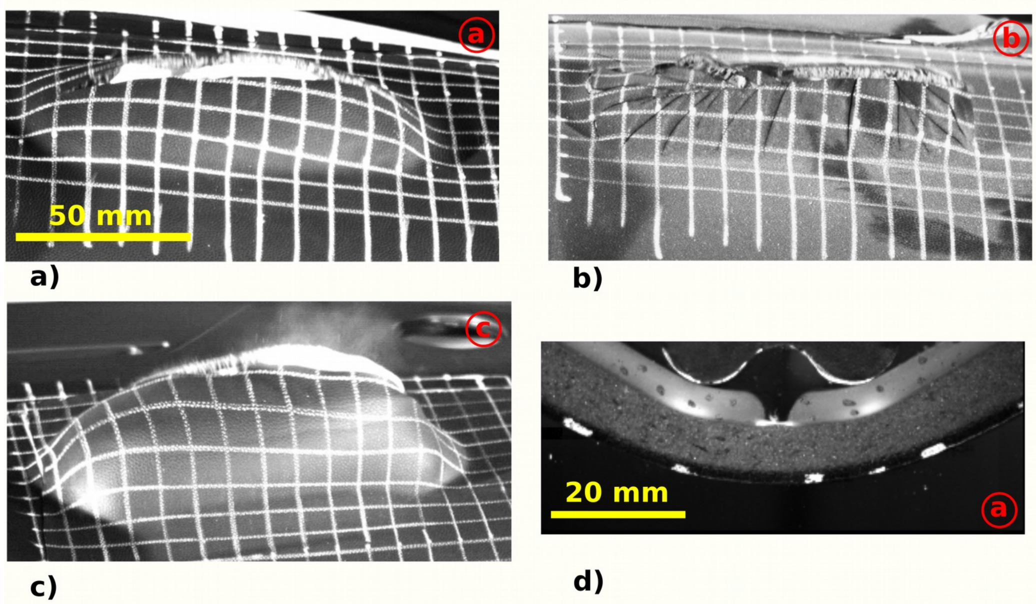

Fig.1 – Test at full scale of an air-bag deployment [1]: a) Correct ductile tearing at 23 °C, b) Brittle failure at -35 °C, and d) Ballooning effect at 85 °C. d) Lab-scale test at room temperature.

3. Conclusions

For an engineering structure like the dashboard, only FE analysis would be efficient for the prediction of the crack initiation to allow the correct deployment of the air bag. To this end, the window of the air bag box, see Figure 1, should be meshed in detail. The three layers of materials as well as the scoring in the PVC skin should be discretized with sufficiently refined meshes. The challenge is to reduce the numerical cost of such a study.

Bibliography

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