

A Study on Fracture Characteristics of Plastics and Application to Head Impact Simulation for Instrument Panels

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ABSTRACT

The instrument panels are made to meet stiffness requirements and also interior safety regulation such as head impact test. Nowadays, CAE is widely used to predict the test results in advance. However, considering fracture phenomena, the characteristics of material takes a significant role for the simulation of the real tests. In this paper, high speed tensile tests and fracture tests of specimens representing typical stress-states were performed to make a fracture criterion of a plastic material (PC/ABS). The suggested method was validated by comparing simulation with test results.

INTRODUCTION

The instrument panel is the interior part of vehicle which needs to meet stiffness requirements and safety regulations. In order to protect the occupant's head in case of crash accidents, the instrument panel has to meet the related regulations such as FMVSS 201 (Northern America) and ECE R21 (Europe). The rigid head form is used in both tests and decelerations are measured to see whether the regulations are met or not. Especially, sharp edges resulting from fractures are not allowed in European head impact regulation.

In the development process of instrument panel, CAE is widely used to predict the test result and improve the crash performance as well. The accuracy of CAE result depends on several factors such as modeling, boundary condition and material behavior. If the fracture is to be considered, more precise material characteristics are required. There have been a lot of researches on plastics for fracture prediction in crash situation. The strain rate effect was the first one to describe the stress-strain behavior of plastics and many OEM, part suppliers and material suppliers have done this research [1,2]. However, when it comes to the fracture of plastics, it is hard to find any reliable and validated prediction method for fracture even though many researches on material characterization are going on [3,4,5].

In this paper, PC/ABS which is the most common plastic material used in instrument panels was chosen and its stress-strain behavior with different strain rates was measured and transformed into an input deck for crash analysis. Also, in order to set up a fracture criterion of PC/ABS, fracture tests representing typical stress-states were carried out to obtain fracture strains for each stress-state. Finally, real head impact test and corresponding crash analysis were performed to validate the suggested method.

TENSILE TESTS WITH STRAIN RATES

Tensile tests with different strain rates for PC/ABS were performed to obtain stress-strain characteristic curves. Low speeds test (0.01, 0.1 and 10 mm/sec) were carried out by universal tensile testing machine (Zwick Typ 1475). For high speed tests at 100, 1000, 7500 mm/sec, hydraulic high speed tensile tester Zwick Typ 1852 was used and strains were measured by optical system [6]. The shape of the specimen is as shown in Figure 1.

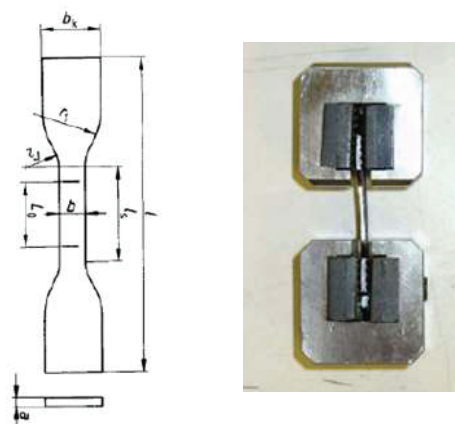


Figure 1. Shape of tensile specimen

Each test at different strain rates was performed with 5 specimens as shown in Figure 2 and the measured

stress-strain data was converted into true stress – strain curves. Also, curve fitting was used to make an average curve from the five 5 specimens. For curve fitting, the combination of several functions and their parameters were chosen to make the best fit for the measured stress-strain curves. The obtained stress-strain curves of PC/ABS at different strain rates are shown in Figure 3.

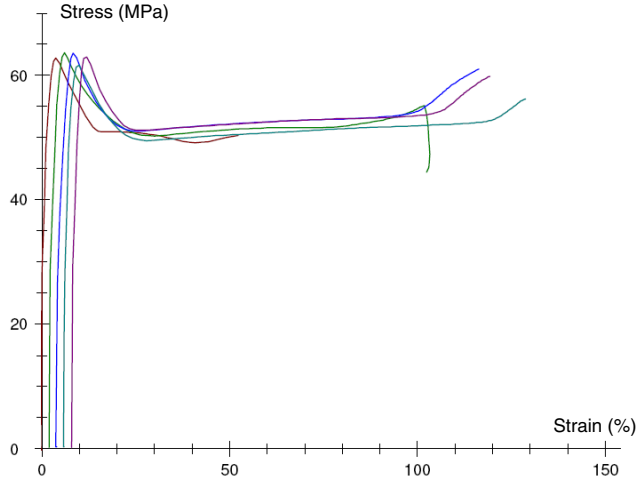


Figure 2. Engineering stress-strain curves from tensile tests of 5 specimens (strain rate = 10 mm/sec)

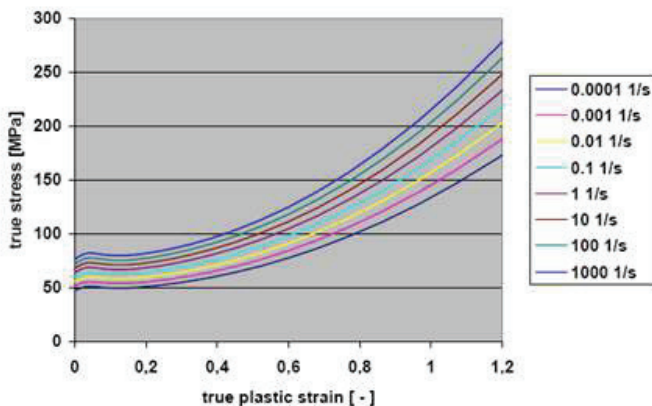


Figure 3. True stress-strain curves of PC/ABS with different strain rates

SIMULATION OF TENSILE TEST

The FE analysis for a tensile test was performed to see if the obtained tensile characteristic of PC/ABS represents well the real experiment. The analysis model is as shown in Figure 4 and the tensile force-elongation curve was chosen for comparison. The commercial crash code PAM-CRASH was used for this analysis.

Five force-elongation curves from experiment and the corresponding curve from analysis result are as shown in Figure 5. As we can see, the analysis result represents well all of the experimental curves in average sense. Concerning the fracture, the analysis model does not include the break of the specimen because this

simulation is only to check the stress-strain curve and the fracture will be considered from the result of fracture tests.



Figure 4. Finite element model for tensile test simulation

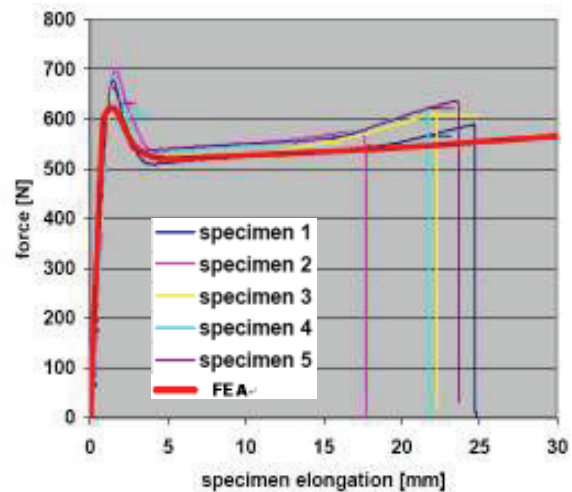


Figure 5. Force-elongation curves obtained from tensile tests and simulation

FRACTURE TESTS FOR SPECIMENS

A set of fracture tests for PC/ABS specimens were performed to make a fracture criterion in engineering point of view. For these experiments, different specimen shapes and loading conditions were chosen respectively to represent three stress-states such as uniaxial, plane strain and biaxial stress states. After applying a dynamic loading, the fracture strains of the specimens were calculated with the measured thickness changes of the specimens and strain calculation formula in Table1.

The magnitude and the speed of dynamic loadings was chosen to cause 50 /sec strain rate at the corresponding specimens because the typical strain rate occurring at head impacts is approximately 50 /sec. In addition, it was founded that the high speed fracture strain (above 50/sec) is different from low speed fracture strain but its variation above strain rate 50 /sec is small.

Table 2 shows the fracture strains for each test and the ratios of in-plane principal strains respectively. The ratio of in-plane principal strains was used as an index to identify each stress-state. In case of plane strain state, the ratio of in-plane principal strains is theoretically zero. But it could not be perfectly zero in real experiment. For this reason, the value of -0.1 was measured.