Analysis of a heterogeneous test for calibration of viscoplastic models

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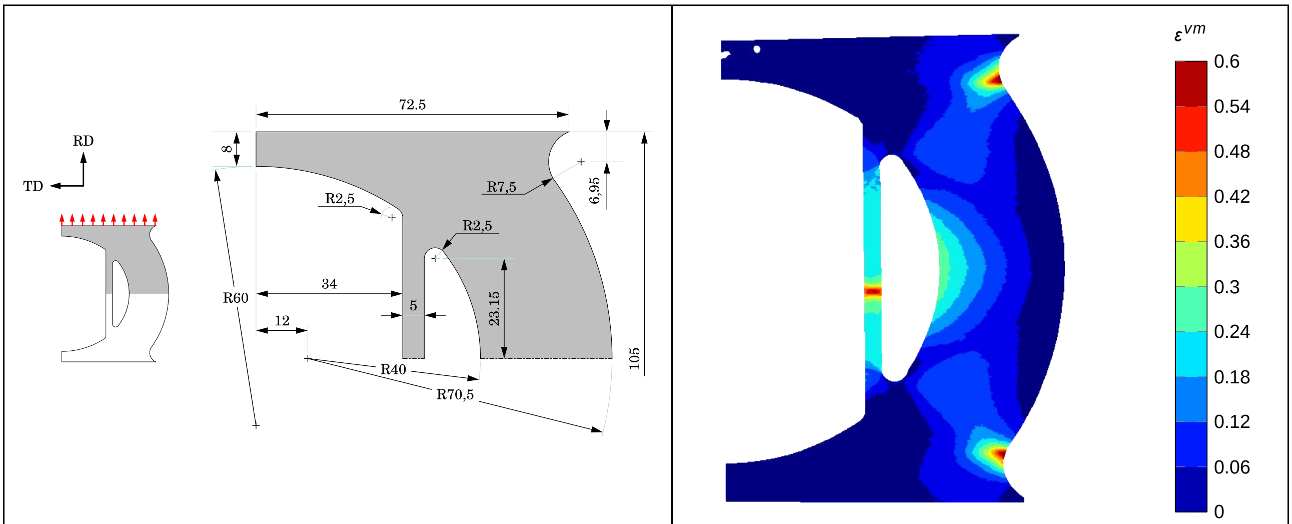
Introduction

The sheet metal forming industry became more and more virtual throughout the last few decades and increased its usage of numerical simulation such as the finite element method. To be able to mimick the forming process, the numerical models request a mechanical model based on anisotropy and hardening, with numerous material parameters. Moreover, for some forming techniques [1, 2], viscous phenomena occur. The classical calibration of the mechanical models, based on quasi-homogeneous standard tests, may become costly and fastidious. Material Testing 2.0 [3] is an interesting alternative for the calibration of models with multiple parameters, based on a reduced number of mechanical tests. This new method uses a heterogeneous strain field produced by the test and measured by full field measurement techniques such as *Digital Image Correlation* [4]. Finally, an inverse method like the *Finite Element Model Updating* [5] or the *Virtual Fields Method* [6] exploits the richness of the kinematics fields to derive material parameters.

Present work

The presented work is based on a numerical study where several heterogeneous specimens subject to a uniaxial loading were studied: a notched specimen [7], a sigma-shaped specimen [8], a D-shaped specimen [9], the “butterfly” specimen [10] and TopOpt specimen stemming from topology optimization [11]. They were first analyzed using numerical simulation with Abaqus software by computing the viscoplastic spectrum [9, 12], to analyze the strain rate distribution during the test. A high strength steel sheet, DP600, of thickness 0.8 mm, is considered. The mechanical behavior at several strain rates, ranging from 10^{-3} up to 100 s^{-1} was characterized with the hydraulic bulge test and a combined Swift and Voce hardening law multiplied by Cowper-Simonds term were calibrated. Then, using those numerical results, synthetic images were generated [13] with the help of MatchID [14]. This step allows us to consider experimental limitations, particularly concerning the resolution of the cameras that will be used. Indeed, the camera resolution is the limiting factor as they do not permit the measurements of strong strain gradients as well as the kinematic fields close to the edges of the specimen. The D-shaped specimen [9] was then chosen, as offering a rich strain rate distribution, without a high buckling tendency, cf. Fig. 1. The numerical simulation was stopped when the maximum equivalent plastic strain reached the maximum value recorded in tension and hydraulic bulge test, as both values are very close. The strain localization occurs mainly in the radius close to the extremities of the specimen, although high values are also recorded in the small ligament. The strain rate distribution, analyzed at several time instants, showed that 2 decades for the stain rate are reached, in several areas with rather high equivalent plastic strains.



(a) Specimen dimensions (in mm). The full size is illustrated on the left-hand side. Only one half is considered in the numerical model.

(b) Equivalent strain distribution measured by DIC in quasi-static conditions

Figure 1: specimen design used in this study, also referred as D-shaped specimen [9].

Two sets of experiments were carried out using the same universal tensile machine equipped with hydraulics grips to make sure that the specimen will not slide, for two average test velocities. The heterogeneous kinematic fields generated during the test were measured by two sets of cameras, depending on the test velocity. For the quasi-static tests, two 12 Mpx cameras are used and offer a spatial resolution equal to 33.45 px/mm. In the case of the high-speed cameras (1 Mpx), the spatial resolution is lower and equal to 11.47 px/mm. To extract the maximum amount of information for each test, the speckle pattern is optimized for each camera set and were obtained by a UV printer that allows to control the dot size and reach the limit of the dot discretization. The high-speed cameras are placed to fit the specimen and to maximize the spatial resolution of the measurements. This optimization of experimental parameters leads to limit the loss of data around the border where the maximal strain value is reached according to the finite element simulation. For both cases, load signal measurements are synchronized with the images recording using a suitable grabber. A qualitative analysis of the test will be presented, like the speckle quality and the measurements resolution. The experimental strain field distribution will be compared with the one obtained with the synthetic images approach and the test richness with regard to the strain rate distribution will be analyzed.

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