

180 Inverse identification of through-thickness shear anisotropic behaviour of sheet metals at large strains

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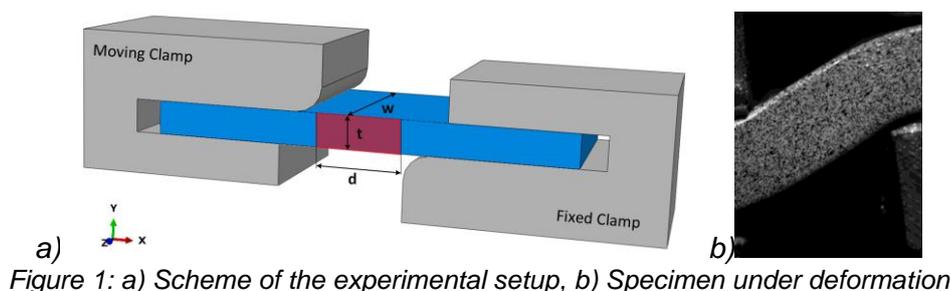
Abstract. In this work, an inverse identification procedure is applied to characterize the anisotropic plastic behaviour of sheet metals along the through-thickness direction involving experimental data from a novel shear test protocol. Digital Image Correlation is used to retrieve the displacement fields on thin sheet metals thickness surface, which are subsequently used as boundary conditions for the identification through Finite Element Model Updating. The proposed characterization framework is used to calibrate the Hill48 model for aluminium alloy AA5754.

Introduction

The increasing interest towards advanced inverse characterization methods requires new experimental procedures capable of collecting a large amount of information about material heterogeneity and anisotropy. An example is given by some applications of the Virtual Fields Method (VFM) [1], which permits to deal with complex material behaviour and geometries thanks to the employment of full-field measurements like the Digital Image Correlation (DIC) [2]. Considering a particular problem, sheet metals are often characterized by an anisotropic behaviour linked to the presence in the material texture of preferential orientations produced by the rolling process. This can represent an important feature for the correct simulation of forming applications or to predict plastic instabilities and failures. Among the years, a large number of constitutive models have been proposed in order to describe such material behaviour, most of them requiring experimental data from different material direction and stress states. However, when a full-scale 3D model is used, for thin sheet metals the calibration of the constitutive parameters regulating the shear anisotropy along the thickness direction represents a challenging operation. In fact, this issue is generally overtaken assuming an isotropic behaviour for the through-thickness shear components, considering especially the planar anisotropy along the rolling and transverse directions. Inverse identification can represent an effective tool to investigate the through-thickness shear anisotropy: for instance, Rossi and Pierron [3] introduce an inverse identification framework for the 3D Hill48 model based on the VFM; Denys et al. [4] employed a stereo-DIC system on a double perforated specimen with a 10 mm thickness to calibrate the 3D Hill48 using the Finite Element Model Updating (FEMU) technique. In this work, the Iosipescu test is modified to evaluate the shear anisotropy of sheet metals along the thickness direction; thus, the corresponding constitutive parameters of the Hill48 model are calibrated performing a *displacement-driven* FEMU identification.

Description of the test

The main idea driving the development of the through-thickness test was to extend the Iosipescu Test to large strain plasticity, producing a combination of bending and shear loads along the specimen thickness. Here, a specimen with length of 70 mm, width $w=20$ mm and thickness $t=4$ mm was cut from a blank sheet of AA5754, taking care to align the rolling direction with the x -axis in Fig.1. The clamping system was arranged so that the length d of the region of interest (ROI) involved in the inverse identification is equal to the specimen thickness.



Displacement and strain fields on the specimen surface were measured involving a 2D-DIC set-up composed of a 2048x2048 CCD camera equipped with telecentric lens to compensate the out of plane movement of the specimen surface. The MatchID software (www.matchidmbc.be) was employed for the correlation analysis, setting a subset size of 37 pixels and a step size of 5 pixels, while strain derivation is calculated imposing a filtersize of 9 points. An example of measured displacement field is reported in Fig. 2 for the last timestep

adopted in the identification. Fig. 2(c) depicts the measured Henky shear strain ε_{xz} , whose maximum values was almost 0.16.

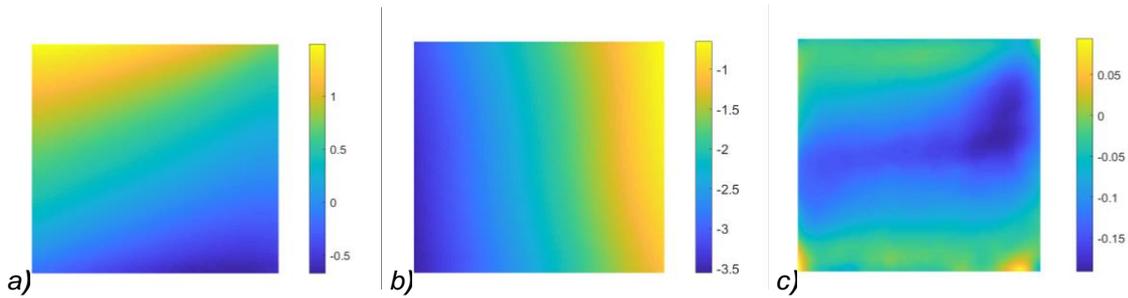


Figure 2: DIC measured: a) Horizontal displacement, b) Vertical displacement, c) Henky shear strain.

Identification process and results

The inverse identification was carried out applying the FEMU technique to calibrate only the constitutive parameter of the Hill48 model [5] regulating the through-thickness shear stress σ_{xy} , while the other coefficients were obtained from uniaxial tests at three different material orientations according to the standard calibration protocol. Thus, the experiment was replicated numerically, creating a Finite Element model of the specimen. Although the bulk of the material presents the typical 2D plane strain condition, the displacement fields tracked with DIC are different with respect to the internal layers, requiring to model the part with 10400 brick elements (C3D4R). Moreover, since sliding of the specimen was observed during the test, the FE model was reduced considering only the volume delimited by the ROI of DIC; thereby, the boundary conditions were assigned extrapolating the planar displacement components U_x and U_y experimentally measured from 30 timesteps. The identification process was accomplished performing an optimization of the sought material parameter minimizing the Root Mean Square Error (RMSE) between the experimental and numerical loading force.

Fig. 3 depicts the comparison between the experimental loading force and the ones obtained numerically assuming an isotropic behaviour and the Hill48 material model, whose identified shear anisotropy coefficient $m=1.149$.

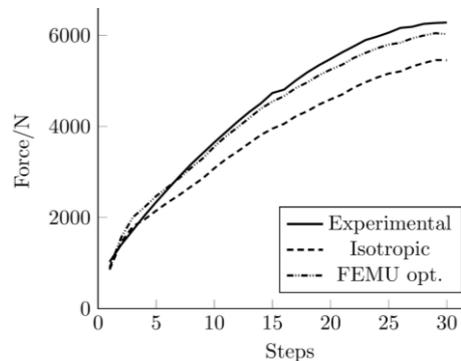


Figure 3: Comparison of loading forces between the experiment, the isotropic case and the outcoming from the FEMU identification.

Conclusion

The identification of the anisotropic shear behaviour along the thickness direction for thin sheet metals was successfully achieved using a FEMU approach on experimental data on AA5754 from a novel shear test.

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