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Estimating the uncertainty range on the elasto-plastic material parameters determined through mixed numerical-experimental techniques

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ABSTRACT

Several standard tests have been developed to characterize the deformation behaviour of metals: tensile tests, torsion tests, etc. The deformation fields which are generated during these tests are homogeneous and do not resemble the heterogeneous deformation fields which occur during real metal forming operations. As a result, the material behaviour, obtained with these standard tests, is an approximation that in many cases proves insufficient to simulate complex forming operations reliably.

To overcome these problems, some authors [1] have performed experiments leading to heterogeneous stress and strain fields, what results in a more complete and realistic material behaviour. The unknown material parameters are identified by means of an inverse method, namely, by minimizing the discrepancy between the experimentally measured and the numerically computed strain fields. The numerical strain fields are computed with the commercial FE code Abaqus/Standard. The experimental strain fields are determined through the Digital Image Correlation Technique. More information about the applied inverse method can be found in [2].

The presented inverse method is applied for the characterization of the hardening behaviour and the yield locus of DC06 steel, based on a biaxial tensile test on a perforated cruciform specimen and a uniaxial tensile test on a perforated specimen (see Fig. 1). The hardening behaviour and the yield locus are described by a Swift hardening law (Eq. 1) and a Hill 1948 yield surface (Eq. 2) respectively:

$$\sigma_{eq} = K(\epsilon_0 + \epsilon_{eq}^{pl})^n \tag{1}$$

$$F(\sigma_{yy} - \sigma_{zz})^2 + G(\sigma_{zz} - \sigma_{xx})^2 + H(\sigma_{xx} - \sigma_{yy})^2 + 2L\tau_{yz}^2 + 2M\tau_{xz}^2 + 2N\tau_{xy}^2 - \sigma_{eq}^2 = 0 \tag{2}$$

with σ_{eq} the equivalent stress (MPa), K the deformation resistance (MPa), ϵ_0 the prestrain, n the hardening exponent, F, G, H, M, N and L the parameters of the Hill yield surface.

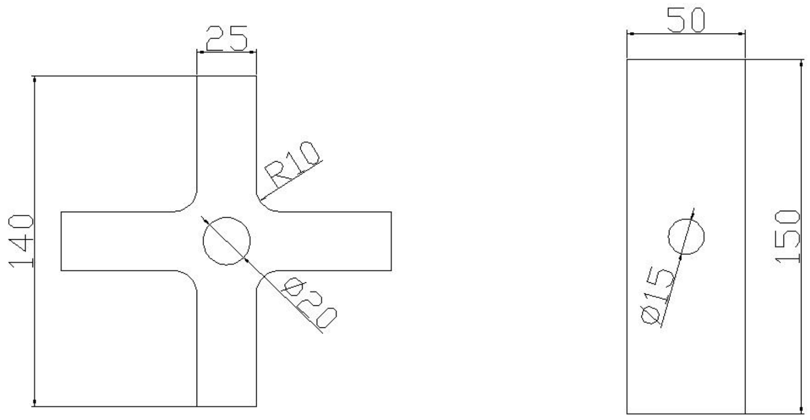

Figure 1: Geometry of the perforated cruciform specimen and the uniaxial perforated specimen.

Parameter	Standard tests		Inverse Methods	
	SSF	LR	Bi-axial test	Uni-axial test
ϵ_0	0.0063	0.0063	0.00253(0.00003)	0.00347(0.000015)
$\mathbf{K}(\mathbf{MPa})$	500	500	493(0.1453)	485(0.1512)
$\mathbf{n}$	0.25	0.25	0.257(0.000124)	0.267(0.000102)
$\mathbf{F}$	0.495	0.26	0.405(0.000195)	0.315(0.000175)
$\mathbf{H}$	0.505	0.665	0.633(0.000168)	0.69(0.00015)
$\mathbf{N}$	1.52	1.27	1.438(0.000484)	1.47(0.00794)

Table 1: Comparison: standard tests vs inverse methods

Table 1 compares the results from the two experiments to the results obtained through standard tests. In case of the standard tests, the Hill coefficients were determined in two ways, namely by means of Lankford ratios (LR) and through Stress State Fitting (SSF). The results are quite similar, except for the prestrain ϵ_0. This can probably be explained by the fact that almost no data at initial yielding is taken into account in the inverse method. The values between round brackets indicate the standard deviation which can be expected on the parameter values if the error on the measured strain fields is estimated to be Gaussian distributed with a mean value of 0 and a standard deviation of $500\mu strain$. This value was computed through Monte Carlo simulation (2000 tests). Therefore the FE model of the two experiments is linearized around its current working point [3].

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