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Identification and identifiability methods of metal sheet parameters

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1. Introduction

The identification of accurate law parameters for metal sheets in the whole range of their deformation field by just one or two tests would be an interesting progress for the efficiency of forming simulations and manufacturing processes. The final aim of this project is to replace classical experimental homogeneous tests by a few tests performed by single point incremental forming process able to reach very large plastic strains.
The identifiability method consists to measure the capacity of a test to identify a material parameter by analysing the sensitivity matrix.
In this work, as a first step, this method is just applied on in-plane mechanical tests. Lagamine finite element software developed by MSM team is used to perform the simulation.

2. Method overview

The set of material parameters are identified using OPTIM module (a home-made optimization code based on Levenberg-Marquardt algorithm).The Reverse Lagamine code computes the sensitivity matrix to the law parameters by a semi-analytical calculation [1]. The parameter sensitivities are based on a finite difference method. The components of the sensitivity matrix at time t_i are defined by the following relation [2]:

$$S_{ij} = \frac{\partial R(\theta_j, t_i)}{\partial \theta_j} \frac{\theta_j}{R_{max}} \qquad \text{Eq. 1}$$

where R is the numerical value of a target result (force, displacement), θ_j is the parameter to identify. The influence of θ_j on the numerical result R is quantified by the level of index value δ computed by the following equation [3]:

$$\delta_j = \frac{1}{N}\sum_{j=1}^{N} |S_{ij}| \qquad \text{Eq. 2}$$

where N is the number of measurement points or the number of steps. δ gives an indication about the influence of the parameter j on the numerical result R. A high value of δ means that the parameter j has an important influence on the numerical result, while a value of zero indicates that the latter is independent on this parameter.

Finally, the identifiability index (collinearity index) is given as follows:

$$I = log_{10}\left(\frac{\lambda_{max}}{\lambda_{min}}\right) \qquad \text{Eq. 3}$$

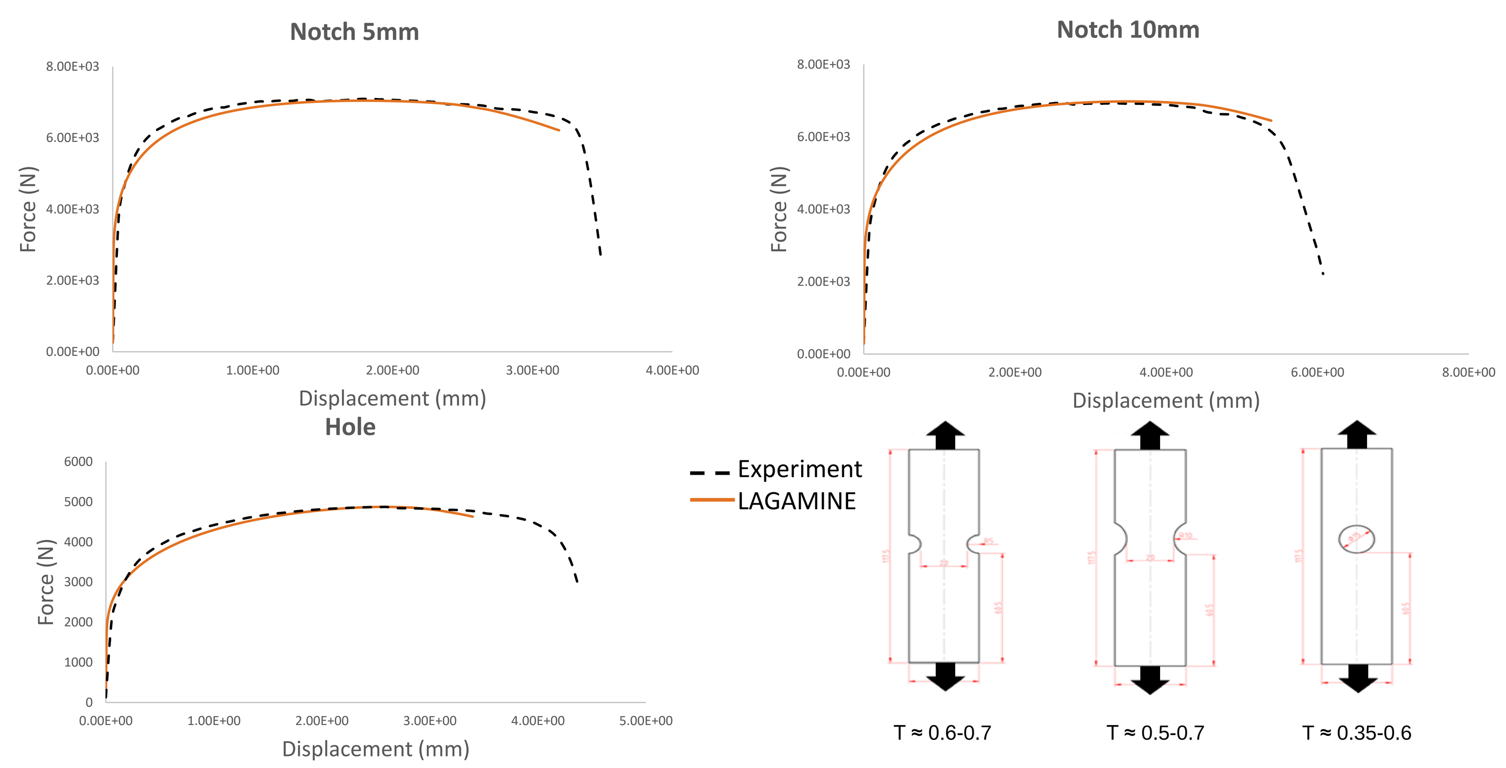
where λ_{max} and λ_{min} are, respectively, the biggest and the smallest eigenvalues of the Fisher's matrix H defined by :

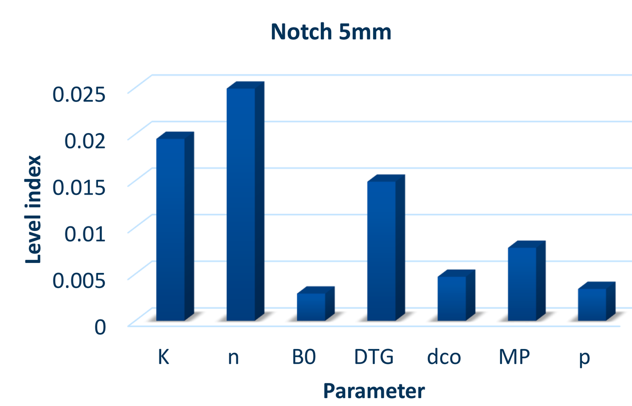
$$H = S^T S \qquad \text{Eq. 4}$$

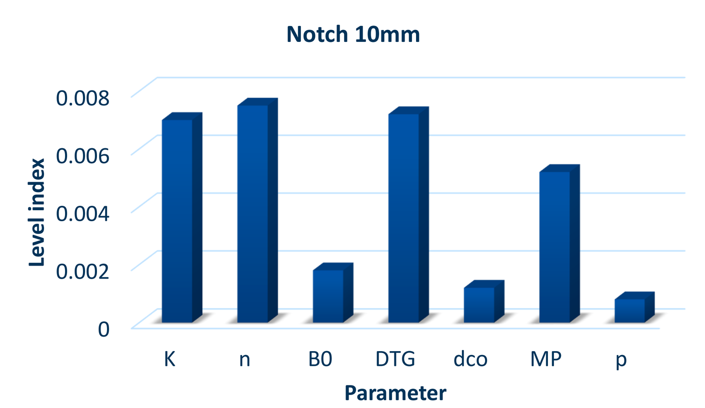
3. Results and discussion

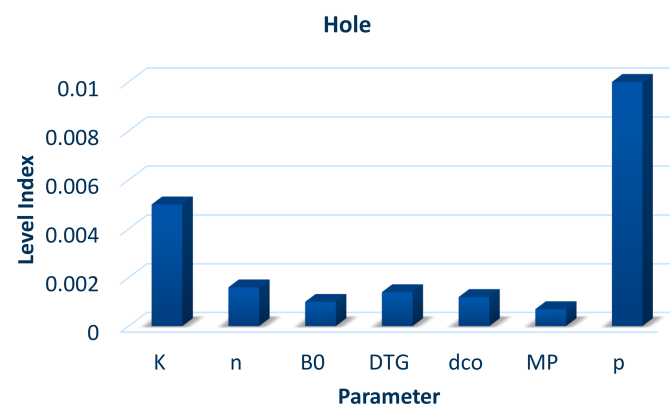
The law parameters are identified through the comparison between experimental and numerical force-displacement curves for a DC01 sheet of 1mm [4].

Parameters of Lemaitre damage model		
Elasticity	E	Young's modulus
	ν	Poisson ratio
Plasticity	σ_y	Initial yield strength (Ludwik hardening law)
	K	Hardening coefficient (Ludwik hardening law)
	n	Hardening Exponent (Ludwik Hardening Law)
Damage	B_0	Initial damage strengthening threshold
	DTG	Damage Strength
	d_{co}	Coalescence limit
	MP	Solpe multiplier
	p	Weight of volumetric energy
	τ	Damage ratio between shear and volumetric damage







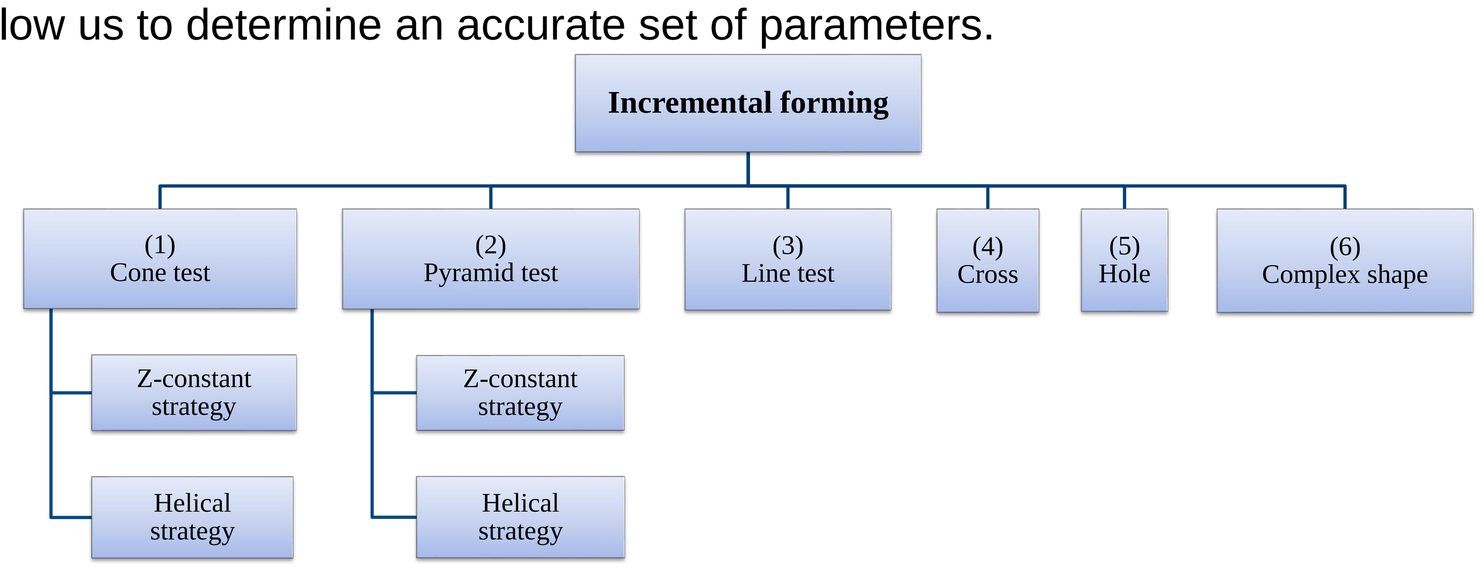


Simulation	Indentifiability Index
Notch 5mm	4.4924
Notch 10mm	4.9655
Hole	3.8366

4. Conclusion

The Lemaitre damage model shows a good capability to predict the mechanical behaviour of the DC01 material under different triaxialities within in-plane mechanical tests.
The sensitivity analysis indicates that the numerical responses (Force-Displacement) are sensitive to the material parameters and specially to the hardening parameters.
Analysing the identifiabilty indexes I, we observe that the hole test with the minimum value of identifiability index is the most appropriate to identify all the material data. Note that, according to [2], SPIF tests generate values lower than 2 for I.

The real goal of this project is to use this identifiability method in order to optimize the tool path of SPIF experiment (strategy and geometry) which will allow us to determine an accurate set of parameters.



5. References

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Acknowledgments

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