Correction of Residual Stresses from Measured Displacements in Springback Simulations

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ABSTRACT

Springback, as used in this context, refers to the generally undesired elastic deformation of sheet-forming workpieces after removing the forming loads [1]. As springback has its origin in the resulting residual stresses, special attention is put in order to characterise it.

The aim of this work is to validate the inverse computation of the residual stresses $\sigma_{res}$ and the incompatible permanent strains $\varepsilon^p$ based on experimental displacements $u_{exp}$.

Two main assumptions are made: the residual stresses are caused by the incompatible eigenstrain distribution, and the eigenstrain remain constant for all configurations in Figure 1. This way, the Finite Element discretisation of the equilibrium condition can be written for domains $\Omega_1$ and $\Omega_2$, respectively as

$$Ku_1 - Ge^p = f_1$$
$$Ku_2 - Ge^p = 0$$

where $K$ is the standard stiffness matrix, matrix $G$ is such that $\int_{\Omega} B^T D \varepsilon^p d\Omega = Ge^p$, with $D$ the elasticity matrix and $B^T$ the transposed strain-displacement matrix. Besides, $f_1$ is the force vector corresponding to the reaction forces in the cast of $\Omega_1$.

We would be left with the following least-square error minimisation:

$$(u_2, \varepsilon^p, f_1)^* = \arg\min_{\varepsilon^p} \left[ \frac{1}{2} \| Ku_{exp} + f_1 \|^2 + \frac{1}{2} \| Ku_2 - Ge^p \|^2 + \frac{1}{2} \| Ge^p - Ge^p \|^2 \right]$$

where $\varepsilon^p_s$ are the plastic strains obtained in the simulation. Note that as this minimisation is not well-posed in the sense of Hadamard, Tikhonov regularisation has been additionally implemented by adding the last term in the functional, where $\varepsilon^p_s$ is taken as a reference value [2].”

REFERENCES
