Digital twin development in metal forming: calibration aided by digital image correlation and artificial intelligence

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The automotive industry benefits from a digital-twin paradigm on metal forming processes to increase efficiency and reduce the delivery-time of parts. The concept of digital twin can date back to Grieves's in 2003 [1]. However, at that time the concept of digital twin was not mature enough due to technology limitations. These virtual products will represent a replica of their physical counterpart, to deliver critical information of the closed loop product lifecycle. This approach should yield innovative solutions, increase the quality of the delivered products, and reduce costs [2].

However, the development of the virtual platform requires the precise reproduction of the material behaviour and the accurate virtual simulation of the forming process. Although simulation of processes by FEM is well established, the calibration of the material constitutive models is still facing open challenges. Accordingly, the digital/virtual replica of the process must deliver the same type of observations, e.g., in terms of full-field deformation measurements. This process increases in complexity for more complex material models, increasing the number of experimental tests needed, which proves to be a time-consuming process due to exhaustive experimental campaigns [3]. To tackle this issue, it is required to use inverse identification techniques that can simplify the experimental campaign without compromising the accuracy of the models. The main point that controls the reliability of the digital twin and its numerical simulations is the pertinence of the representation or modelling of the mechanical behavior of the material and, in particular, the material parameters of the constitutive equations involved in the model [3]. Nowadays, one of the real challenges concerns the determination of the material parameters with an optimal quantity of information to guarantee the ultra-reliability of the predictions.

In this communication, a Ph.D. project is presented. This Ph.D. work aims to design a metal forming digital twin through: (i) the calibration of the constitutive models using advance VFM techniques; (ii) the approximation of the digital/simulation and experimental worlds via synthetic images construction; (iii) the development of an enhancer/corrector for the existing well-known models using artificial intelligence. This corrector module, using machine learning (ML) techniques, modifies the stiffness of the analytical material models formulation, providing flexibility to the hybrid module leading to an even better calibration and reproduction of the material behavior and (iv) the experimental validation using heterogeneous kinematic full-field measurements. The Arcan experimental apparatus will be used to calibrate an anisotropic elastoplastic model to an aluminium alloy and a DP-steel. The experimental data will be used to train the ML-corrector.

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