Analytic and numerical models for digital twins in sheet metal bending: A computational study

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Abstract

The demands on quality of industrial metal forming processes are constantly rising. To meet all requirements, reliable computational models are needed that can be integrated in digital twins of production lines. In the following we look at the example of sheet metal bending where the workpiece is thin compared to the lateral dimensions. The process is highly nonlinear because of material behavior, contact, and large deformation.
So far, numerical models are based on the Finite Element Method (FEM). There is no doubt that the results are reliable, as is often proved by experimental validation. However, if numerical models are to be used in a digital twin, two main problems arise: First, the license costs of commercial Finite Element software are very high. In our group Abaqus has been successfully used for a long time in research and development. One aim of the present work is to find out whether the open-source software Code_Aster is a suitable alternative to model and simulate metal bending. Secondly, if a digital twin has to be real-time capable, a Finite Element Analysis (FEA) usually requires too much computing time. Therefore, the second aim of this work is to find out whether an analytic model based on Euler's Elastica would be representative of this industrial process.

For our analytical model, we consider a cantilever beam subjected to a transverse follower force on the free end, which is a good approximation of the load case in the industrial process. Using the theory of Euler's Elastica, we consider large flexural deformations but assume inextensibility in longitudinal direction. An analytical solution is presented. The results are then verified by FEA for the special case of a linear elastic material with large deformation. Models based on 3D continuum elements are implemented in Abaqus and Code_Aster. The simulations are performed for different parameter combinations in order to compare analytic and numeric results, the computation times, and to determine the validity limits.
The results show good agreement between the two Finite Element solutions. Parameter studies confirm that the analytic results are representative of the industrial process over a wide range, and clearly show the limitations, especially for the profile angles and the length-to-thickness ratio of the workpiece. Finally, future extensions of the proposed theory are discussed and the next steps to integrate the analytical and the Code_Aster Finite Element model into a digital twin of sheet metal bending production lines are outlined.

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