Lagrangian and Arbitrary Lagrangian Eulerian Simulations of Roll Forming Processes

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ABSTRACT

In the industry, cold roll forming is more and more used as a manufacturing process mainly for its high productivity and its close geometric tolerances. Moreover, it is a convenient way for forming materials with high mechanical properties getting rid of the limitations particular to the classical deep drawing process for such materials (the increasingly required press power, the sheet tearing. . .). As a result, attempts to simulate roll forming by the finite element method are multiplying in the literature. However, most of these simulations are restricted to the sheet to sheet process - the sheet length being smaller than the whole roll forming line – because the numerical models rely on a Lagrangian kinematics that is not very well suited for the forming of long sheets in a reasonable computational time. A first reason is that the size of the model rapidly increases with the strip length due to the large number of finite elements that is required to get an accurate solution, leading thus to time consuming simulations, the worst case for a Lagrangian simulation being the continuous process simulation. Secondly, some transient dynamic vibrations may occur each time the sheet hits a roll forming tool and enters a forming stand. These vibrations are responsible for complex sliding contact conditions and a slowdown of the convergence rate of the time integration process. Thirdly, the Lagrangian model can be quite sensitive to the sheet length and the boundary conditions applied on this smaller sheet and may at the same time lack robustness, especially when the sheet is unable to enter a forming stand without any help from the operator. Two promising approaches are presented in this paper: the Arbitrary Lagrangian Eulerian formulation as well as the parallelization of the algorithms. In contrast to the classical Lagrangian approach, the Arbitrary Lagrangian Eulerian (ALE) formalism which consists in decoupling the motion of the material and the mesh has the capability to overcome these problems and to simulate the continuous process for the whole roll forming line at reduced CPU cost by optimization of the mesh. In the particular case of roll forming, the mesh nodes are fixed in the rolling direction but are free to move in transverse directions. Taking advantage from this approach, the mesh is only refined in the neighborhoods of the forming tools for accurate modeling of contact and bending. The numerical simulation starts with an initial guess on the sheet geometry hopefully leading to the steady state. This initial geometry is built by the interpolation from the flower diagram of the mill simplifying the beginning of the simulation in terms of contact conditions. In addition to the ALE formalism, parallel computing is another technology increasingly used nowadays in scientific computations to largely improve computational performances and is highly profitable for such an application. In the present paper, the numerical results are presented and compared to some experimental data on a U-channel in order to validate both Lagrangian and ALE models. Furthermore, advantages of the ALE formalism are highlighted with the simulation of a tubular rocker panel on a 16-stands forming mill, which is a real industrial mill. The results for the roll forming of a C cross section will be presented with both Lagrangian and ALE formalisms. Finally, the speedup from parallelization is discussed. All these developments have been implemented in our in-house finite element code METAFOR.