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Integrated Simulation Process Chain: From 3D Roll Forming Design to Crash Analysis

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Abstract. This paper presents an innovative numerical simulation process chain for sheet metal profiles, addressing the full workflow from tooling design and 3D roll forming process simulation to crash simulation. The process begins with defining the bending sequence and the corresponding tooling, tailored to the specifications of a 3D roll forming line. A dedicated preprocessor creates "ready-to-run" finite element models, ensuring an accurate representation of the complex deformation behaviour. Those models include the meshing and material description of the blank and the kinematics used in the process. The simulation employs hexahedral elements, suitable to capture the material flow, strain distribution, contact interactions and workpiece geometry during forming and after springback. To bridge the gap between forming simulations and downstream structural analysis, the roll forming results are mapped onto shell elements commonly used in crashworthiness simulations. A specialized algorithm allows for this transformation, preserving deformation history and enabling the seamless integration of roll forming data into downstream structural analysis. The use of roll forming simulation data in subsequent structural analysis has a significant impact in the quality of those analysis. This holistic approach enhances the fidelity of product performance predictions, offering a robust framework for optimizing forming processes and end-use structural integrity.

Keywords: 3D Roll Forming; Crash Analysis; Finite Element Analysis; Mapping

1 Introduction

Finite element analysis (FEA) allows to develop and optimize manufacturing processes and products without requiring any manufacturing efforts. COPRA® FEA RF is the leading FEA solution for simulating roll forming processes, enabling manufacturers to predict material behaviour and optimize production. [1,2,3]
Often, roll formed profiles are not standalone products but integral parts of larger assemblies. The automotive industry, for example, relies on roll formed profiles in vehicle manufacturing, where structural integrity is critical. Crash analysis is a key application of FEA in this sector, helping engineers assess and enhance vehicle safety. [4]

However, the full stress and strain history of roll formed profiles is often lost, as there is no direct bridge between roll forming simulations and subsequent crash analyses. This gap can lead to reduced accuracy in structural predictions. By incorporating the complete deformation history of roll-formed components into crash simulations, engineers can significantly improve the reliability of their analyses and make more informed design decisions.

2 Results

A comprehensive workflow was developed, Fig. 1. This workflow begins with the conceptual design of the 3D roll forming process, tooling design and process planning. Next, the tool kinematics are defined, and the roll forming process is simulated using COPRA® FEA RF. The workflow also includes machine design and control. As a result, both the physical roll formed profile and detailed FEA results are obtained, enabling the integration of accurate stress and strain data into subsequent crash simulations for improved predictive accuracy.

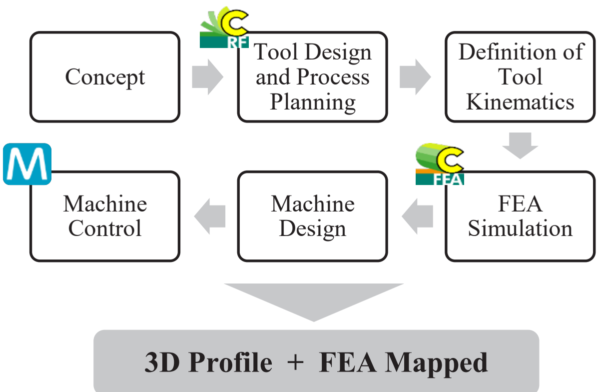

Fig. 1. Workflow from 3D Roll Forming Design to Crash Analysis

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Fig. 2, Fig. 3 and Fig. 4 show 3D roll forming simulation results, equivalent von Mises stress, sheet thickness and total equivalent plastic strain, obtained from COPRA® FEA RF and the respective mapping into LS-DYNA® for subsequent analysis.

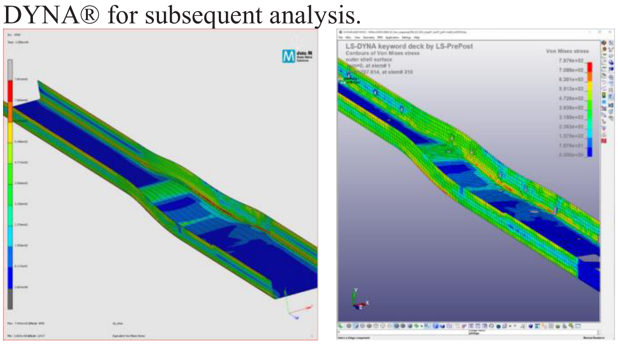

Fig. 2. Equivalent von Mises Stress, COPRA® FEA RF roll forming simulation (left), mapping to LS-DYNA® (right)

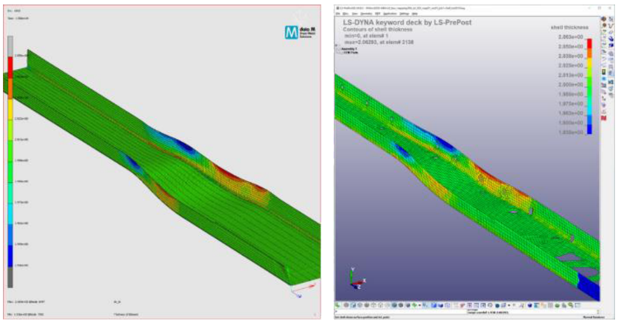

Fig. 3. Sheet thickness, COPRA® FEA RF roll forming simulation (left), mapping to LS-DYNA® (right)

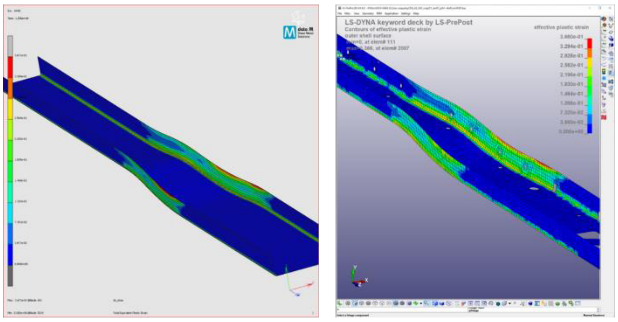

Fig. 4. Total Equivalent Plastic Strain, COPRA® FEA RF Roll Forming Simulation (Left), Mapping to LS-DYNA® (Right)

In Fig. 5 one can observe how using simulation results from a 3D roll forming simulation (figure on the right) opposed to use a stress-strain free roll forming profile (figure on the left) as an initial condition in a crash simulation influences the obtained results.

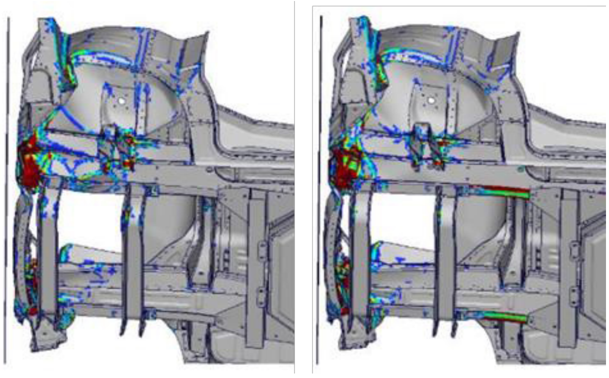

Fig. 5. Frontal Crash Simulation Results, without mapping (left) and with mapping (right)[EDAG]

3 Conclusions

A streamlined workflow has been successfully implemented, integrating the development of a 3D roll forming manufacturing process, its simulation, and the subsequent mapping of the results into another FEA package for crash simulations.

This advancement enables the roll forming industry to deliver FEA results alongside its corresponding roll formed profiles or machines. These results can then be incorporated into further numerical analysis, such as crash simulations.

The use of roll forming simulation data in subsequent structural analysis has a significant impact in the quality of those analysis. This holistic approach enhances the fidelity of product performance predictions, offering a robust framework for optimizing roll forming processes and end-use structural integrity.

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