Roll Forming Simulation with PROFIL and LS-DYNA

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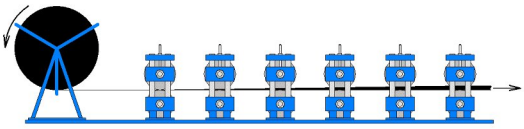
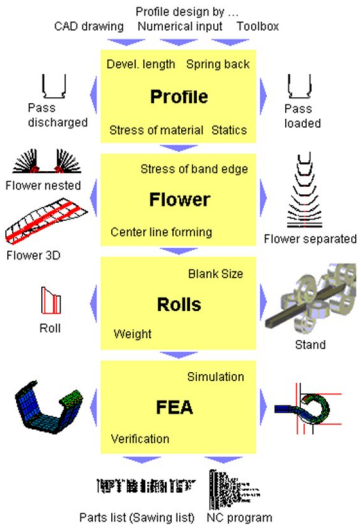
1 What is Roll forming?



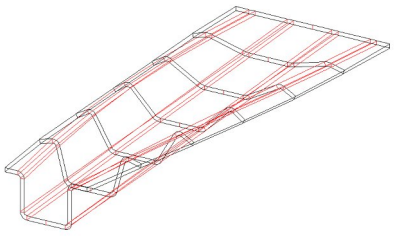
Roll forming is a continuous bending operation in which sheet or strip metal is gradually formed in tandem sets of rollers until the desired cross-sectional configuration is obtained. Roll forming is ideal for producing profiles with long lengths or in large quantities.

2 Preparing the roll forming operation



Each profile cross section needs a customized set of roll tools. First, after defining the final profile cross-section, the flower pattern has to be designed. This means, starting with the final section, the cross section of the profile in each stand is defined by unbending the arcs. Afterwards, the rolls have to be designed by deriving the roll contour from the profile contour in each stand.
A special roll forming problem is the longitudinal strain within the sheet (see below). To avoid remaining strain and unwanted deformations, it is necessary to check just in time, if the longitudinal stress does not meet or exceed the yield stress. During flower pattern creation, the stress can be checked approximately by the “Stress of Band Edge Calculation” or by the “Profile Stress Calculation” (PSA), both are features of the design software PROFIL.
After completion of the roll design, the FEA method can be used for a final check. It also helps to evaluate if the designed roll tools are able to form the desired profile with the given allowances.
The last step is to export the manufacturing data like parts list (sawing list) and the program for the CNC lathe.

3 Strain and stress in the longitudinal direction

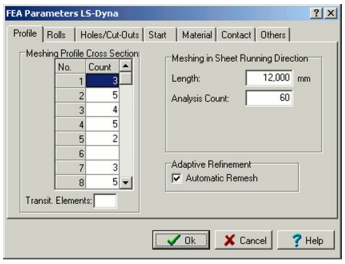


Exactly this is the problem: if single points of the sheet cross-section are tracked, movements on curves with different lengths are observed. The result is different strain and stress of the material. As long as this occurs within the elastic bounds, strain disappears again after the profile leaves the final stand of the roll forming machine and the desired profile form can be obtained. If, however, the yield stress is exceeded, remaining strain arises. The local "too much" of material causes unwanted deformations like rippled edges, mostly in case of symmetric profiles. If the profile is non-symmetric, twists around the longitudinal axis or curved profiles can result. When this occurs, time-consuming and expensive modifying of the roll tools is necessary [1].

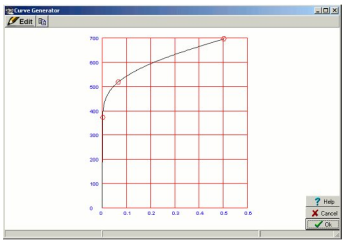
4 FEA (Finite-Element-Analysis) simulation

The simulation of the roll forming process enables the designer to get very precise information about stress and strain within the profile while running through the roll forming machine and after leaving the final stand of the machine. Furthermore it calculates the profile shape that is formed by the designed rolls. To enable the designer to benefit from the FEA result without being an FEA expert, the design software PROFIL has a built-in interface to the leading FEA system LS-DYNA from Livermore Software Technology Corp., USA.

5 Preprocessor

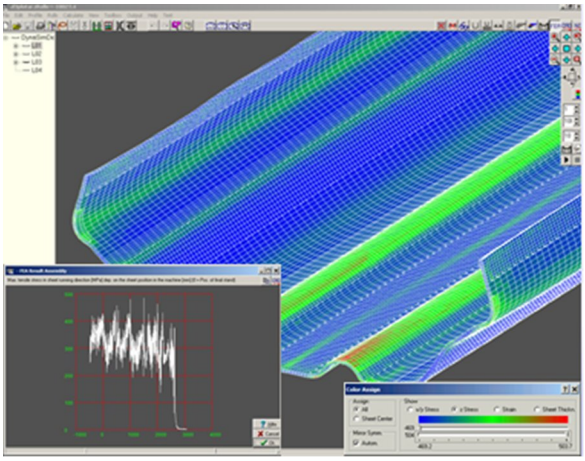


After designing the flower pattern and the roll tools the parameters for the simulation like meshing longitudinal and transversal, material, contacts etc. are entered. Then PROFIL creates the files for the LS-DYNA solver with the simulation model by key-press. Four nodes shell elements are used, with 5 through thickness integration points. If prepunched sheet should be roll formed, the holes/cut-outs simply can be defined in a 2D CAD drawing with any shape and position. The drawing is saved in DXF format. PROFIL extracts the holes/cut-outs from this file and creates output files for the solver with trimming curves.



Often the exact stress-strain-curve of the used material is not available and cannot be obtained shortly. Nevertheless the designer wants to proceed an FEA simulation with approximate values. The curve generator is a handy tool for creating a stress-strain-curve quickly by defining three characteristic curve points. The three points are: Yield point, tensile breaking stress point, and a medium point that controls the bulge of the curve. The curve has a tangential connection to the Hookean line and is continuously rising with rising strain [2].

6 Postprocessor



The postprocessor opens the LS-DYNA output files (file format .d3plot) and shows the result on the PROFIL screen. In case of symmetric profiles, only one half is simulated because of saving calculation time. The postprocessor adds the second half by mirroring. Graphs are created that show the transversal and longitudinal stress, the strain, and the sheet thickness reduction as a function of the sheet position in the machine. These graphs are tailored to the special needs of roll form designers and help to evaluate the FEA result.
Sectional views of the sheet within the rolls, at any machine position, or after leaving the machine are created by key-press. The rolls can be inserted (as 2D cross section or as 3D solids alternatively) in order to check the position of the sheet within the roll tools. Inserting the designed flower pattern enables target/actual comparison. The assignment of stress and strain to colors can be modified by movable sliders. Optionally, stress and strain of the top and bottom sheet surface can be shown or of the sheet center only. The simulation is proceeded by using a strip with a user-defined finite length (in reality, the strip nearly has unlimited length). Because the behavior of a finite and an unlimited strip is different, the leading and the rear edge can get unrealistic deformations. In order to mask this affect out during evaluation, a selectable count of rows can be cut off at the leading and the rear edge [3]. If errors are detected in the final profile, the simulation can be restarted at the stand whose rolls had to be modified. This saves computation time.

7 Summary

The goal of the FEA simulation is to systematize the roll form design process that was based on experience and know-how in former times. The designer can get more safety that his designed rolls are able to form the desired profile shape with the desired allowances.

8 Literature

[1] Brandegger, R.: “Predicting stress and strain in roll formed profiles”. The Fabricator May 2004 Vol. 34 No. 5, Rockford IL USA, Page 56-57.
[2] UBECO GmbH: “Rollform Design Software, What’s New? – Rel. 5.1”. Publication Oct. 2013.
[3] UBECO GmbH: “Rollform Design Software, What’s New? – Rel. 5.2”. Publication Oct. 2014.